DIGITAL IMAGE PROCESSING USAGE EXAMPLES FOR EXPERIMENTS WITH CONCRETE

Martin Salák, *

Department of Concrete and Masonry Structures, Faculty of Civil Engineering,
Czech Technical University in Prague, Thakurova 7/2077, 166 29 Prague 6, Czech Republic.
martin.salak@fsv.cvut.cz

ABSTRAKT

Tento článek spojuje tři praktické experimenty tím, že se zaměřuje na zpracování informací s důrazem na image processing. Zobrazovací technologie nám otevírají široké možnosti jak se dívat na beton, s každou technologií však přichází také výzva v interpretaci dat z měřícího přístroje. První experiment za použití počítačové tomografie (CT) usiluje o vytvoření podrobného RBSM modelu přesně podle scanovaného modelu, včetně umístění plniva uvnitř objemu betonu. Druhý v čase sleduje nasákání ozářeného betonového vzorku díky neutronovému skenování a ve třetím experimentu byla použita kamera s vysokým rozlišením na měření příčné deformace zatíženého vzorku v raném stáří tvrdnutí, když jiné měřící techniky se zdály nevhodné.

KLÍČOVÁ SLOVA

image processing • beton • ozáření • zobrazovací metody

ABSTRACT

This articles connects three practical experiments with focus on image processing. Screening technologies offers us wide range of possibilities of measuring concrete, but every screening method needs to be interpreted with image processing. We would like to introduce three examples. One where computed tomography allows us to create rigid body spring mesoscopic model with aim to model exact propagation of cracks. Second where neutron radiography is used to capture water propagation through irradiated sample, and third where high resolution camera is used, when other measuring techniques fail.

KEYWORDS

image processing • concrete • irradiation • RBSM • screening technique

1. INTRODUCTION

Computers cannot see the same way humans do, but if we teach them what to look for, their sight surpasses ours by far. Digital image processing is used widely all around us; It recognises faces, letters, or car models and licence plates, and when it comes to analyzing experiments, it provides invaluable tool.

In this paper we would like to describe and evaluate three examples of usage of image processing in experiments. First, creating a 2D rigid body spring model of a concrete bar with high fidelity to reality, where script uses X-ray images to distinguishes between different parts of concrete to create the model. As a second application we used image processing to analyze water absorption of cement samples exposed to gamma-ray irradiation by analyzing the pictures made by dynamic neutron radiography imaging. And thirdly the usage of high resolution camera to measure lateral deformation when regular method were not suitable.

2. EXPERIMENTS

2.1. RSBM model based on computed tomography scan

When it comes to modeling concrete, we are usually modeling it as homogeneous material. This is absolutely sufficient when it is needed to find the linear distribution of forces on a structure, but when it comes to more precise tasks and we zoom our interest from the whole structure down to detail, it would be good to take into consideration that concrete is composite material consisting of aggregate, cement paste and air bubbles. When concrete is modeled as heterogeneous material, then mesoscopic simulation can be done, that should result in very realistic representation of given structure. For such case finite element method is not very well suited because of high demand on computer power for solving non-linear tasks, for this exact case rigid body spring model (RBSM) was invented and it is used for this experiment (Kawai 1978). Rigid body spring model works by dividing sample into rigid bodies - they are inspired by watching destroyed concrete divide into small parts. These bodies are connected together with springs, so any internal forces or deformation are visible only on deformation of springs, rigid bodies stay intact.

Small scale sample 10x10x80 mm was scanned using computing tomography (CT). CT, by taking pictures from more angles, has the ability to create 3D image of scanned sample. The scanned images were then processed to create three 3D STL models of sample's aggregate, cement paste and air bubbles. The 3D model of sample's aggregate is shown in the figure 1.

To simulate exact behaviour of sample under load, it is necessary to take into consideration where the aggregate is located. It is the goal of this experiment to simulate propagation of cracks as close to real sample as possible (crack will go through through cement paste rather than through aggregate). That's why the aggregates are cut parallel to one side of the sample near its boarder as visible in figure 2 to be modeled into 2D RBSM to simulate its behaviour.

As rigid body spring method is inspired by observing the nature (Kawai 1978), so is the chosen mesh - the shape of rigid bodies - voronoi partition is the chosen pattern of RBSM. Voronoi partition is pattern visible in nature for example on drying mud or the pattern of giraffe, it is most easily described as a pattern created by

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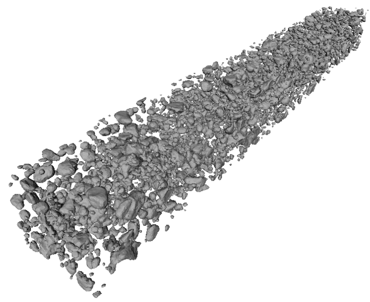

Figure 1: *3D stl model created after CT scan*

boubles when they are squished together. 2D example is shown in the figure 3.

With voronoi patterned 2D slice of real concrete sample, it is possible to create rigid body spring model and simulate its deformation.

2.2. Water absorption of irradiated cement samples

Porosity and permeability are highly watched parameters of concrete structures, because of their high influence on durability of the structure. This experiment follows up on contemporary research that investigate influence of gamma-ray irradiation on early age mortar (Rezaei-Ochbelagh et al. 2010) (Ochbelagh et al. 2011) and it focuses on water ingress of cement samples.

Small-scale cement samples are made, irradiated (maximum 8.7 hours long exposure) at very early age - 1.3 hours after first contact of cement and water. At the age of 15 hours the samples are submerged in acetone to stop the hydration process, then they are dried at 50°C in an oven and until examination they are kept wrapped in polyethylene foil in a box with silica gel to reduce the risk of any moisture ingress.

To inspect the water absorption, the samples were put in an aluminium container with 2mm of MilliQ water with 18.2 MΩ/cm resistance and to ensure unidirectional water flow, aluminium tape was put around each sample as visible from figure 4.

In the table 1 all the samples are listed, to evaluate how the irradiation affects water absorption, samples Ni (not irradiated) and Ir-8 (iradiated for 8 hours and 40 minutes) are compared. In order to capture the water propagation through the sample, radiography images were taken at least every 1 minute throughout the experiment. (Khmurovska et al. 2019)

To process the images from neutron radiography the noise is reduced using median 5 by 5 pixel filter, then the colors of sample submerged in water as and dry sample are set as threshold values and fitted function of water density for every color (intensity of neutron beam) for the exact composition of the experiment is created. In order to fit the function a phantom sample in the shape of wedge was created (see figure 5 from aluminium (which doesn't affect neutron beam) filled with water. After that water content for each point picture from neutron radiography - that is line trough the sample along the line of neutron beam - can be calculated.

The experiment showed that irradiated sample uptakes water slightly more quickly and deeper inside, but overall water ingress is a little lower. It might be caused by radiation decreasing pore diameters, thus increasing pore pressure in the sample.

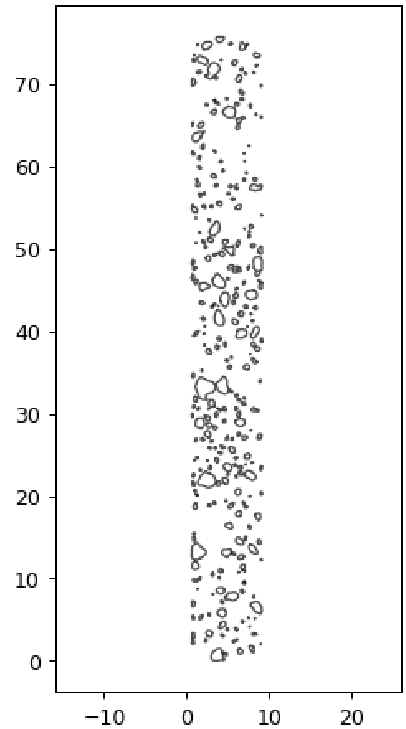

Figure 2: *Cut through the sample*

2.3. latitudal deformation measurement

When it comes to fast construction process of concrete structures, it is necessary to know not only compressive strength and modulus of elasticity, but also Poisson's ratio at early stages of hardening of the concrete (that is from the time when it is possible to demold the specimen up to one day of age). To examine the Poisson's ratio it is needed to measure the lateral deformation of the specimen. Though regular contact methods are not suitable for not fully hardened concrete(Štemberk & Kohoutková 2005) there are contact-less methods.

One of the easiest method is using high resolution camera combined with image processing. It uses high resolution camera to capture the specimen (Štemberk & Kohoutková 2006) or the shadow of the specimen to get rid of optical effects water on top of the specimen have (Tran 2006) as shown in the figure 6. Then the bitmap file is converted to arrays of digits where each digit is equal to gray scale difference between neighboring pixels. The edges are detected automatically as there is the greatest difference, and the width of the specimen under load can be calculated. The change of width was measured only as relative change so it is not needed to convert between pixels and millimetres.

3. CONCLUSIONS

Three experience were introduced: Preparation for rigid body spring model based on computed tomography of concrete sample, thus being able to create a very real meso scale model, that takes into consideration position of aggregate in the sample.

Then analysis of neutron radiography scan of cement sample absorbing water. That took pictures of not irradiated and irradiated sample continuously during the time when the samples were in contact with water to evaluate effect of low dose gamma-ray

Table 1: *All the samples for water absorption experiment.*

Sample [-]	Time of Irradiation [hours]	Dry Weight [g]	Imbibition Time [hours]	Wet Wight [g]	Water Content [g/cm^3]
Ni	0	3.39	12.00	3.97	0.29
Ir-2	2.17	3.36	49.00	3.98	0.31
Ir-4	4.33	3.33	22.67	3.88	0.28
Ir-6	6.50	3.28	22.67	3.89	0.30
Ir-8	8.67	3.40	12.00	4.01	0.30

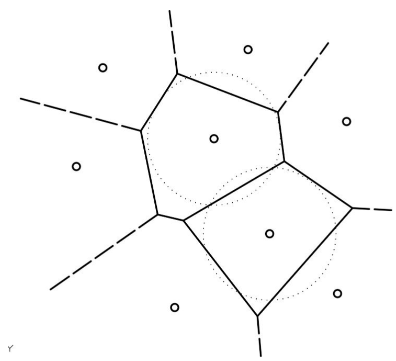

Figure 3: *Voronoi partition example*

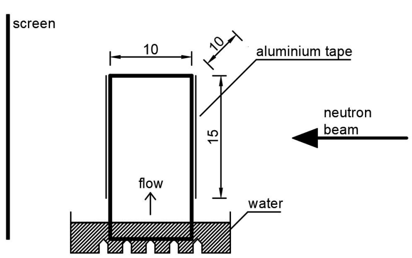

Figure 4: *Absorption captured by neutron radiography*

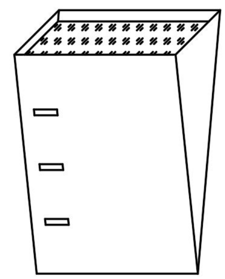

Figure 5: *Phantom sample - aluminium wedge filled with water, with marks at known thickness*

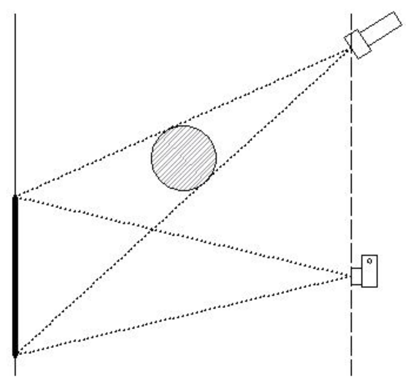

Figure 6: *Capturing the shadow on a whiteboard.*

irradiation on concrete samples.

And at last measuring technique of lateral deformation was described that used high resolution camera when regular methods were not usable. The camera captured sample's shadow find lateral deformation to compute Poisson's ratio of early age concrete.

All of the experiments show how invaluable tool image processing is, especially when it comes to nondestructive testing of concrete structures. Technology allowing us have better screening techniques requires us to follow with interpretation in image processing.

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