AUTOMATIC MAPPING OF CONCRETE STRENGTH IN STRUCTURAL ELEMENT

Roszilah binti Hamid[1], Ramizi bin Mohamed[2], Khairul Anuar Mohd Nayan[1], Siti Aminah binti Osman[1] and Kamarudin Mohd Yusof[1]

[1]Department of Civil and Structural Engineering
[2]Department of Electrical, Electronic and System
Engineering Faculty,
Universiti Kebangsaan Malaysia,
43600 UKM Bangi, Selangor D.E. Malaysia
E-mail: roszilah@eng.ukm.my

ABSTRACT: Collapses of structure under construction can be prevented if quality control is practiced at sites. The strength uniformity of reinforced concrete structure element cast on site depends on the level of compaction of the fresh concrete. The whole element should be checked and mapped so that localized defect can be detected and removal of formwork can be stopped if applicable. A portable and quick way to check and map the uniformity and the strength of concrete has been developed utilizing the use of pressure wave and signal processing techniques. An echo is introduced to the sample by dropping a small steel ball from a certain height from the concrete surface. The impact generates stress wave, which propagate through the concrete. The accelerometer receives the wave and changes the display from time to frequency domain. The highest observed frequency is determined as the depth frequency. The velocity is calculated as $C_P = 2fD$. Hundreds of specimens were tested. The relationship between the strength and the velocity is correlated. From correlation equation, the strength of concrete can be estimated within 10% error (Hamid et al, 2004). The mapping process is done automatically in computer-generated program. Signal-processing techniques were used to compute the data; Fourier Transform to translate a time-series signal into frequency domain, concrete strength calculation, interpolation technique and a Graphic User Interface (GUI) to complete the mapping algorithms.

Keywords – automatic mapping, strength, concrete structural element, signal processing

1. INTRODUCTION

Every now and then, we are astounded by news of collapses of structures under construction. Not only that we lost some capitals, but also lives, which has tarnish the civil engineers credibility. What are the reasons of the collapses of the structures under construction? One of the most important reasons is the poor quality control practice on site. The structural elements are cast on site according to stages, beginning from the foundation up to the roof. The concrete cast on site is required to have achieved a specified strength before the formwork can be stripped off and the construction on other elements commences. To determine the strength of the cast element, 3 cubes with the same mix of that the cast elements are sent to the laboratory before the stripping of the formwork. The problem with cast on site concrete is, the level of compaction is not uniform throughout the element, especially at heavily reinforced area where the compactor cannot reached in-between closely spaced bars, resulted in honeycomb concrete. The whole element needs to be checked and mapped so that localized defect can be detected and removal of formwork can be stopped, if applicable.

2. METHODOLOGY

A portable and quick way to check the uniformity and the strength of concrete has been developed utilizing the use of pressure wave. An echo is introduced to the sample by dropping a small steel ball from a certain height from the concrete surface. For vertical component such as column, the ball is swing from side like a pendulum from a certain distance and for element only accessible from underneath, gun-like equipment is used for the trajectory of the ball upward. A low frequency stress wave will propagate through concrete and reflect back to the surface. The transducer will receive the reflected waves and record the time taken for the wave to travel to the opposite surface of the concrete and back to the tested surface. The dominant frequencies, which appear as peaks in the spectrum, are associated with multiple reflections of stress waves within the structure, and they provide P-wave speed, C_P. The highest observed frequency (*f*) is determined as depth (D) frequency. The velocity of wave through the concrete (C_P) is calculated as:

$$C_P = 2fD \qquad (1)$$

The correlations between the pulse velocity C_P and the strength of hundreds of concrete cubes, slab and reinforced concrete beams are suggested which is:

$$f_c = 0.1797e^{0.0014V} \qquad (2)$$

Results show that the estimated strength is within 90% of the measured strength (Hamid et al, 2004).

Previously, the highest peak magnitude (*f*) of the frequency domain is read manually from the frequency spectrum and inserted into equation (1) to obtain the velocity of pressure wave in concrete. Next, to obtain the estimated strength, the C_P value is inserted into equation (2).

Manual reading and manual input requires longer time to produce result especially if the area to be checked is large such as floor slab, thus this study develop another computer program to map the strength of each points automatically.

2.1 Data Computation

Based on the suggested correlation, a software computer program is written in graphical manner to plot the strength mapping of the complete structure elements, such as floor slab, ground beam and such. It is a computer-simulated program based on the real data collected on site. The method of measurement is based on the collective measure for a well structured coordinates on its surface. Every coordinate corresponds to the region of measured strength, where the frequency of the reflected propagated wave is then detected. Figure 1 shows the flow chart showing how the data are computed. First, real data in time domain obtained at site is saved as text (*.txt) file and transformed into frequency domain using Fast Fourier Transformation. Next, peak detection technique is employed to detect the maximum magnitude of the frequency domain. The highest frequency (*f*) is determined as depth frequency. The velocity of wave through the concrete (C_P) then can be calculated using equation (1).

2.2 Mapping Process

In every file it contains all the information required to fully compute all the requirement of automatic mapping numerically. The fundamental components contained are time-series digitized signal, the sampling frequency, the coordinate, the sampling size, time sampling array and etc. A few signal-processing techniques were employed to compute the data to become a complete mapping process. First and foremost is Fourier Transform to translate a time-series signal into its frequency domain, thresholding of frequency values, concrete strength calculation, interpolation technique and finally a Graphic User Interface (GUI) to complete the mapping algorithms. Figure 2 shows the mapping process of the concrete structural element strength.

Data Computation:

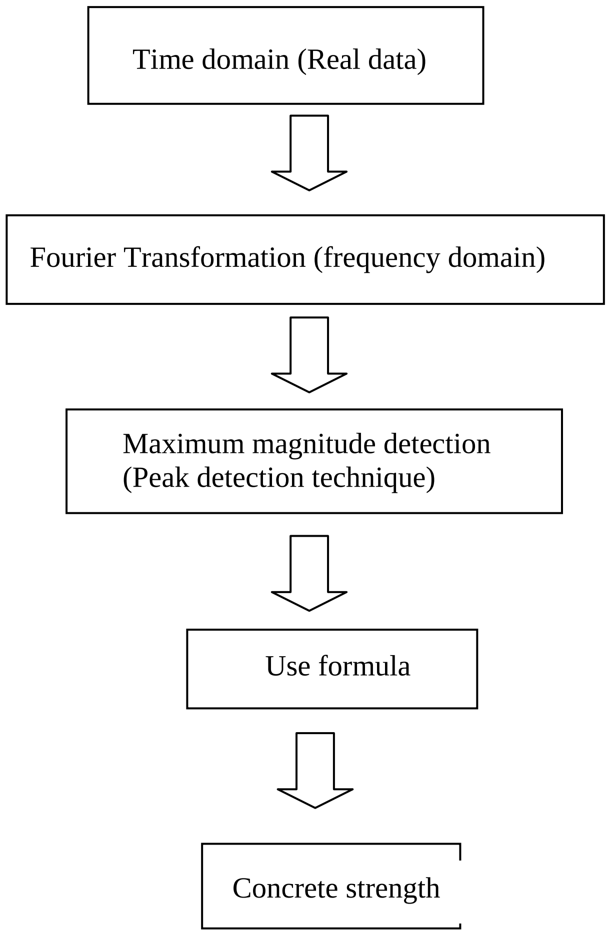

Figure 1. Flow chart of Data Computation

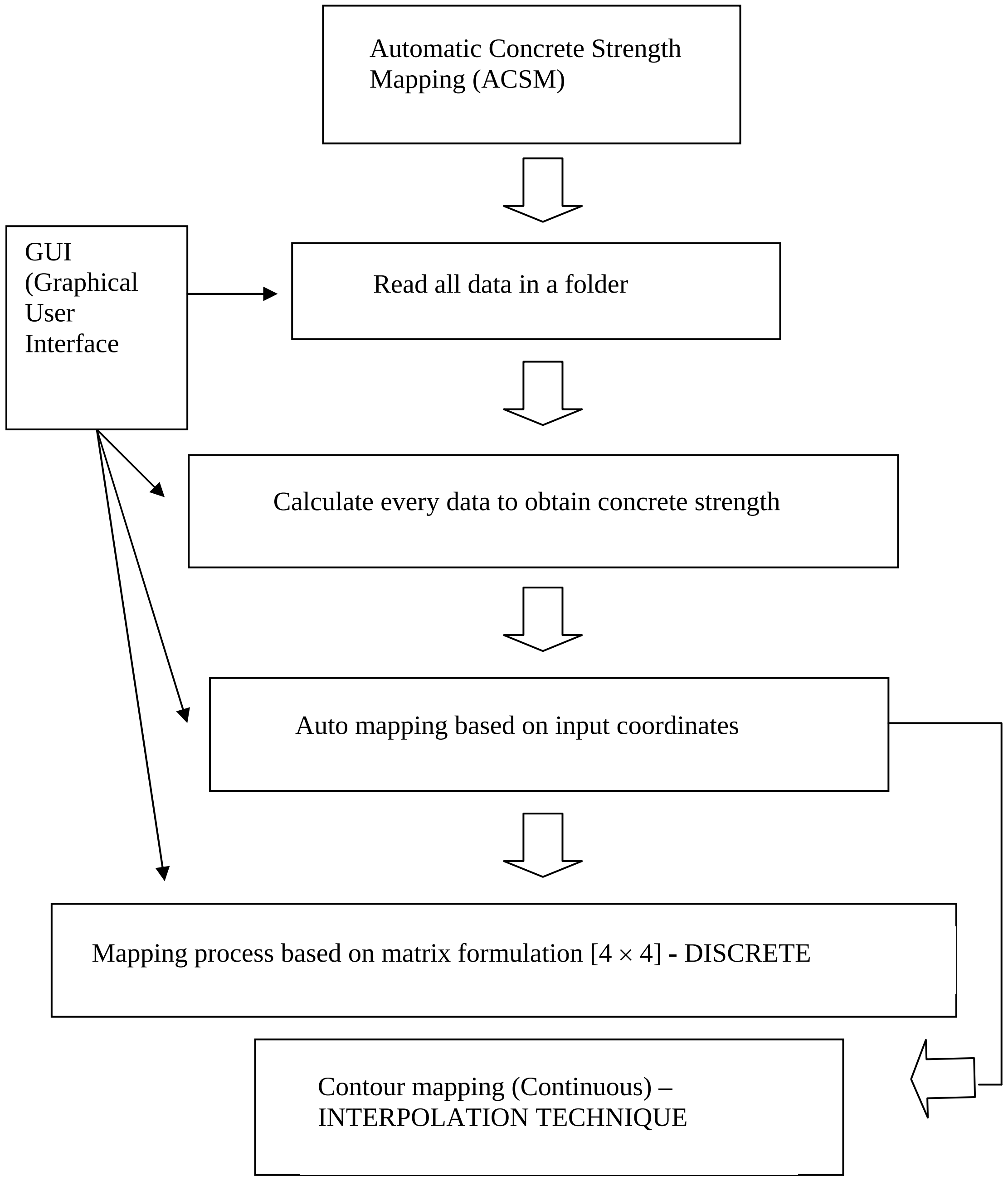

Figure 2. Mapping process of the concrete structural element strength

3. RESULTS AND DISCUSSION

Figure 3 shows the data saved as text file (.txt) is is displayed as waveform in time domain plot for coordinate (1,3).

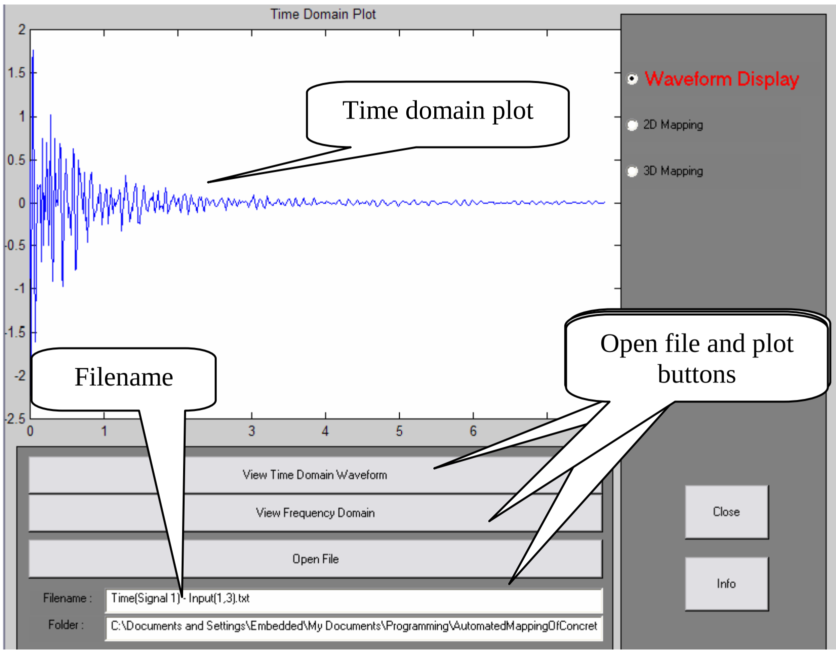

Figure 3. Time domain waveform of single measurement at coordinate x = 1, y = 3

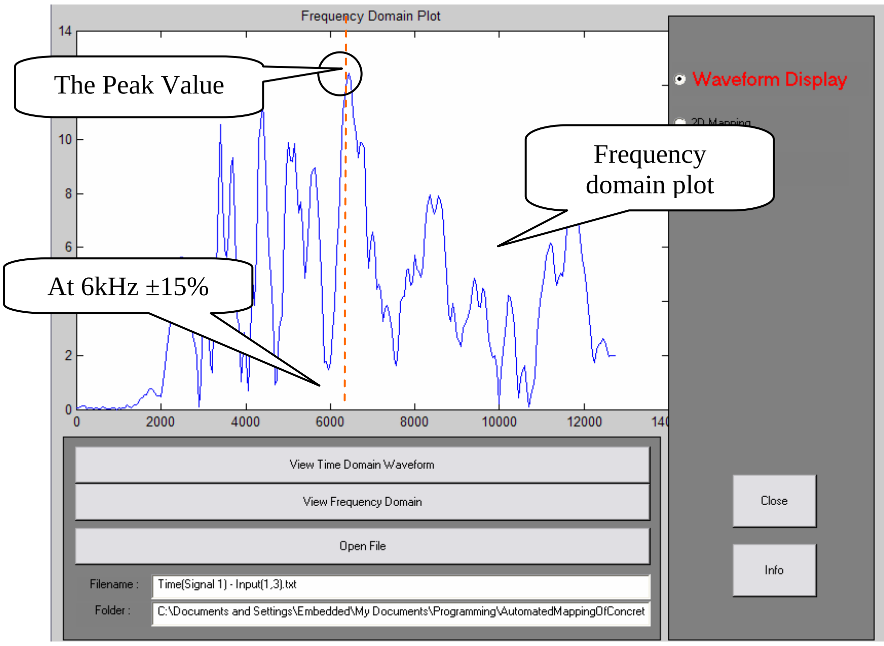

Figure 4. Frequency domain waveform of single measurement at coordinate x = 1, y = 3

Next, Figure 4 shows the time domain plot is transformed into frequency domain plot using Fast Fourier Transformation. The peak value is determined using the peak detection technique.

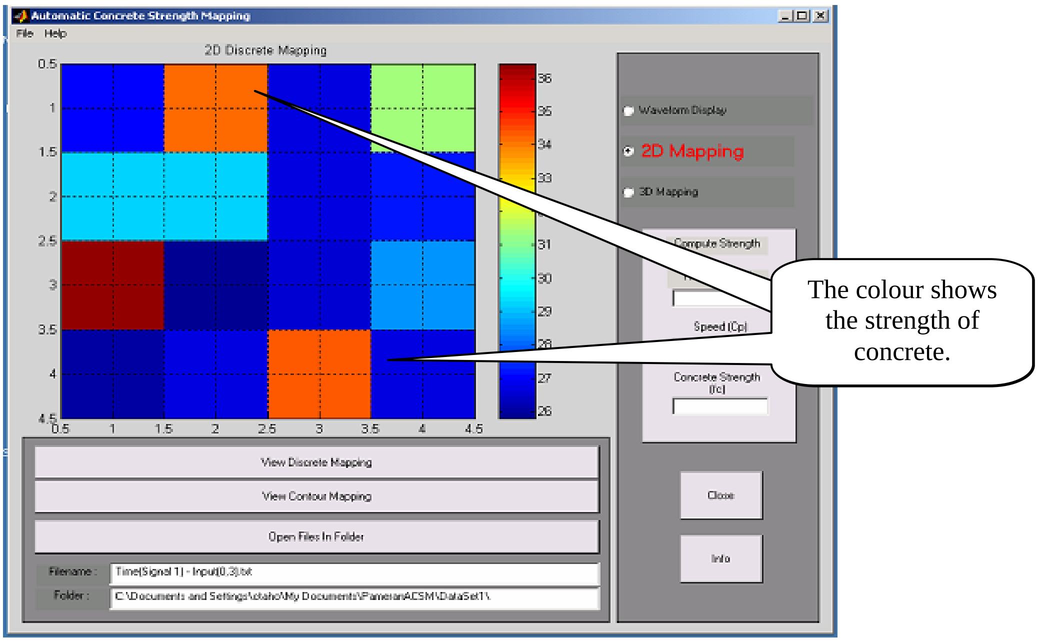

Figure 5. The Final Concrete Strength Mapping

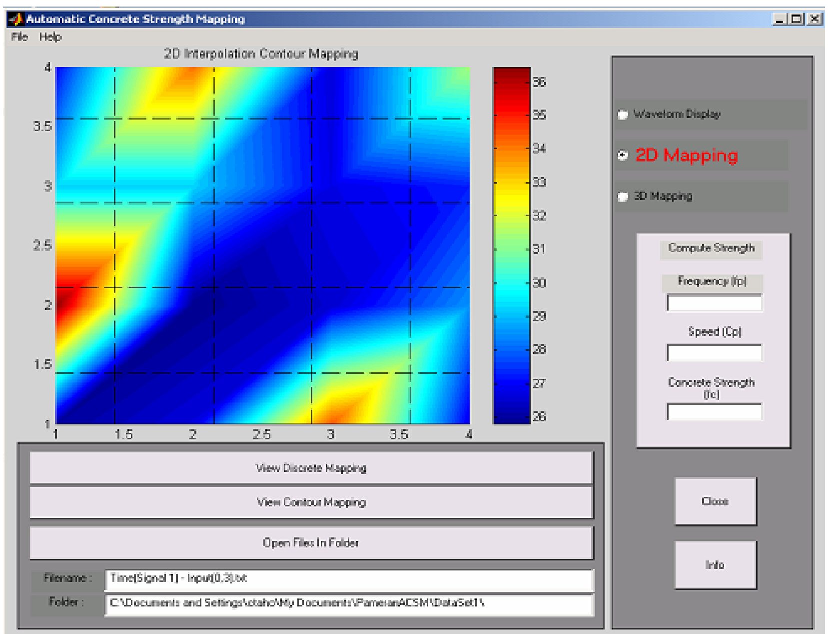

Figure 6. Contour mapping (continuous) using interpolation technique

Finally, the above steps are repeated for each data. The square feet area of specified region measured is entered into the programme. An automatic grid of each measured coordinate will be generated automatically once the program is prompting to the folder of 'all collected data'. Figure 5 shows final concrete strength mapping once the concrete strength is calculated, interpolation technique is used for contour mapping and a Graphical User Interface is applied to complete the mapping algorithms. For this type of display, the mapping process is based on discrete matrix formulation [4 × 4]. The display can be changed into contour mapping (continuous) using interpolation technique as shown in Figure 6.

The concrete structure element strength mapping then can be printed and handed to the contractor for safety assurance of formwork removal or for corrective measures, if there's any. Numerous repetition of measurement can be done once the area is grid in case of formwork removal withholding until the attainment of the desired strength of concrete or later on for maintenance purposes.

4. CONCLUSION

The strength of a structural element at a particular point can be estimated using the formula establised earlier. Subsequently, the whole area of the structural element can be grid and the strength of the concrete at each point can be mapped using signal processing technique.

5. REFERENCES

R. Hamid, K.A.M. Nayan, K.M. Yusof & Y.W. Chua, 2004, *Assessing Concrete Quality Using The Impact Echo Method*, Prosiding Persidangan Kebangsaan Ke3 Kejuruteraan Awam (AWAM2004), Pulau Pinang, 2004, pp6C06 1 – 6C06 5