CHAPTER 5

CONCLUTIONS AND SUGGESTIONS FOR FURTHER WORK

5.1 Conclusions

Based on the experimental observation, the following conclusions can be drawn.

1. The work in this thesis opens a new direction for the application of cement-based piezoelectric composite in civil engineering. The material and techniques developed in this work have a great potential in application of health monitoring of building and infrastructures.

2. All piezoelectric ceramic-PC composites were successfully fabricated using normal mixing and compacting method. The result showed that the electrical properties of the composites increased with piezoelectric ceramic particle size. The enhancement in the electrical properties was contributed to less contacting surface between the cement matrix and the piezoelectric ceramic particles. Furthermore, piezoelectric ceramic of median size of 450 μm can be produced and it gave the highest electrical properties.

3. The property of ceramic and the volume ratio of ceramic/ cement will affect d_{33} and g_{33} value greatly and higher content of piezoelectric ceramics is results in higher d_{33} and g_{33} value in 0–3 type cement-based PZT composites. However the acoustic impedance will need to be considered when tailoring PZT ceramic content for an engineering application.

4. The polarizing conditions largely influence the piezoelectric behavior of cement-based piezoelectric composites. The piezoelectric properties are better when a higher voltage and longer duration are applied.

5. The 0–3 cement-based piezoelectric composites show typical ferroelectric hysteresis loops at room temperature. With the increase of the piezoelectric ceramic volume fraction, both the remnant polarization P_r and the coercive field E_c increased. The remnant polarization displays little asymmetric behavior in the hysteresis loop curves compared with the hysteresis loop of the piezoelectric ceramic, that of the composites are far from saturation because of presence of a non-piezoelectric cement layer between the piezoelectric ceramic particles.

6. The piezoelectric properties (d_{33} and g_{33}), dielectric constant (ε_r) and dielectric loss ($tan\ \delta$) were determined as a function of volume fraction of PVDF in the composite. It was found that a limited amount of PVDF of about 5.0 vol.%was optimum for enhancing the dielectric and piezoelectric properties of the composites. With this amount of PVDF added, the d_{33} coefficient increased when compared with the composite without the third phase filler. Too much of PVDF usage, however, reduced the piezoelectric activities of the composites due to its excess insulator phase.

7. The electrical properties of the composite present work compare with the basic properties of PZT, cement paste and concrete of previous work are listed in Table 5.1

Table 5.1 Electrical properties of cement piezoelectric composites

Materials	Vol%	ε_r (at1 kHz)	d_{33} (pC/N)	g_{33} (10^{-3}Vm/N)	ρ (10^3kg/m^3)	Ref
PZT-SH	100	3643	513	15.9	7.5	[7]
Cement paste	100	~56	-	-	~2.0	[7]
Concrete	100	-	-	-	~2.4	[7]
PZT-PC	50:50	94.2	12.5	15.0	3.73	[79]
PVDF	100	12	32	-	1.78	[27]
This work						
PZT	100	~1000	198	21	8.0	
PZT- PC	50:50	374	18	16	5.57	
PZT-C-PC	50:1:49	237	22	18	5.61	
PZT-PVDF-PC	50:5:45	145	24	26	5.51	

5.2 Suggestions for further work

A number of interesting question remain unanswered concerning the relationships between microstructural evolution and electrical properties of the cement-based piezoelectric composite. Thus, it was anticipated that this could be party filled by the following suggestions for the further work

1. The electromechanical coupling coefficient k_t with thickness vibration of plate is used to represent the degree of polarization of cement-based piezoelectric ceramic composite. And the dependence of thickness and shape of specimen, poling temperature and applied voltage on the degree of polarization of cement-based piezoelectric ceramic composite would need to be considered.

2. Further work on higher poling field in poling process and the effective ways that improve poling degree are to eliminate the interface pore, the cement matrix pore

and their inner water, which can be implemented by enhancing compact press and drying the samples in a vacuum box would need to be considered.

3. Further works on connectivity such as 1-3, 2-2, and 3-3 and another piezoelectric ceramic such as PMN-PT and non-lead piezoelectric ceramic are recommended.