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The Defect Monitoring of Micro Steel Fiber (MSF) Concrete Using Acoustic Emission Technique

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Abstract: Concrete is an essential building material for construction industry. The strength and the performance of the concrete will be deteriorate as the age of the concrete due to extreme weathers and cracking. The main goal of this study is to monitoring the concrete conditions using Acoustic Emission (AE) technique. Therefore, a series of concrete prisms with size of 100 mm × 100 mm × 300 mm with specified percentage (0, 0.5, 0.75, 1.00,1.25) of micro steel fiber (MSF) were produced to conduct AE test. The results obtained from AE test were dicussed in term of real crack observation, b-value, and RA value. Apart from that, a series of concrete cube with the size of 100 mm × 100 mm × 100 mm were batched to conduct compression test. As a result, a highest reading of 74.50 kN was obtained at the 28th day of curing for the specimen contained 1.25% MSF. Meanwhile, there is an occurence of a macro-crack in the middle of the specimens. Also, as the load increases the macro-crack further developed until the specimen fracture. Besides, a highest value of 95 dB to 100 dB amplitude were obtained. This proves that there were macro-cracks on the surface of specimens. From the analysis of RA-value, the presence of the tensile cracks had contribute to the failure of concrete specimens. Therefore, this study contributes towards real time concrete structure defects monitoring. Through the AE technique, the maintenance cost can be reduced at the same time the defects can be located at an eraly stage.

Keywords: Acoustic Emission, Micro Steel Fibers, Cracking, RA Value, Amplitude, Real Crack Observation

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1. Introduction

The popularity of concrete as a building material in the construction industry is well known. This is due to its relatively high compressive strength properties. In Malaysia, reinforced concrete is a composite material that most commonly being used during construction. However, to improve concrete performance and workability, additional material can be used. Nowadays, many researchers had been carried out using one of the materials which are micro steel fiber to be added as an additional material in concrete. Fibers can be found in various shape and sizes which is from steel, polymer, and others. To produce quality concrete, adding the additional material in concrete is compulsory. It has been proved that different types of fibers added in specific percentages to concrete improves the mechanical properties, durability, and serviceability of the structure (Aamir Hussain Wani et al., 2017). As known, micro steel fiber is a common fiber that is used in concrete.

Concrete is formed from a mixture of cement, sand, coarse aggregate, and water with a specific ratio. Ordinary cement has a low tensile strength and little resistance to cracking. Concrete is widely used in construction material. Many experiments were done in different types of material to improve the properties of concrete. Use of fiber in mixture concrete is not new but there is a change in percentage, types, and size of fibers. The main reason why mixes the concrete with fiber is to improve the strength and workability of structure. It is also used to improve the performance of concrete. The weakness of concrete can be removed by

The inclusion of fibers in the mixture (C. Selin Ravikumar et al., 2015). Acoustic emission testing is used to monitoring the structural integrity of the concrete. It has been extensively applied to concrete structures. Acoustic emission testing also can determine the position of cracks in the entire structure without damaging the structure. Acoustic emission testing has usually been used because of the advantages of the AE method which is a high sensitivity, and global monitoring capability. In the past decades, some researchers focused on damage identification of concrete and AE testing had a rapid development. The testing used the velocity waves and it has two types of signals, burst and continuous signals. Acoustic Emission is widely held to be a sensitive method which offers significant advantages in terms of early fault detection and diagnosis when compared to other monitoring methods (Hutt, Clarke, Evans, 2018). It is also can be used to analyse the different types of damage occurring in composite materials. Therefore, this study is mainly focusing on the micro steel fiber concrete monitoring using Acoustic Emission method.

2. Materials and Methods

2.1 Materials Preparation

Materials that were used in this research :

i. Ordinary Portland Cement Type1
ii. Fine Aggregates (FA) passing of (0.075-5) mm
iii. Coarse Aggregates (CA) passing of (5-20) mm
iv. Water
v. Micro steel fibers with 12 mm long and 0.25mm width

2.2 Design Mixing

This method show the materials that used for this research. Calculation made by size of mould, DOE method and volume method. Table 1 shows the quantity of the materials required during the fabrication process.

Table 1. Total weight of materials used

Quantities	Cement (kg)	Water (kg)	Fine Aggregates (kg)	Coarse Aggregates (kg)	MSF (kg)
Per m^3	405	195	545	1265	865
0.023 m^3	9.32	4.49	12.54	29.10	19.90
Control	9.32	4.49	12.54	29.10	0
0.5 %	9.32	4.49	12.54	29.10	0.099
0.75%	9.32	4.49	12.54	29.10	0.15
1.00%	9.32	4.49	12.54	29.10	0.20
1.25%	9.32	4.49	12.54	29.10	0.25
Total	**46.60**	**22.45**	**62.70**	**145.50**	**0.699**

2.3 Specimen and Test

A total of 15 specimen were used for a cubes (100mm x 100mm x 100mm) and a prisms (100mm x 100mm x 300mm) in size respectively. The mixes were prepared and started with control specimens which is 0% of micro steel fibers followed with 0.5%, 0.75%, 1.0% and 1.25% of MSF added into the mix. All the concrete specimens were tested after 7-days and 28-days of curing process. The compressive test was conducted based on BS 1881-116:Part 116: Method for the determination of compressive strength of concrete. The acoustic emission test was conducted on the prism aged 7 days of curing. 2 sensors with an amplifier (R6I type) were mounted on the left and right sides of the prism specimens as shown in Figure 1. While Figure 2 shows the setup of the acoustic emission test. Before proceeding the AE monitoring, the threshold level was set at 45 dB. Next, the gradient line was set on the layout to determine crack location easier. Then AE win software was setup with relevant information before conducting the test. After the configuration procedures were completed, a load was applied to the prism specimen.

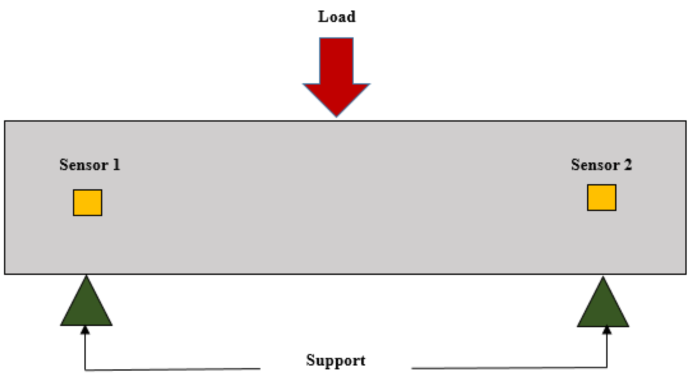


Figure 1: Setup of Acoustic Emission (AE) sensors

Figure 2: Setup of AE test

3. Results and Discussion

This topic cover a detailed information on the result of the study achieved from the testing works and analysis of the data generated. In this division, it covers the methods of analysis of AE data parameter that were employed for detail analysis on the crack's identification. In addition, the problem met potential errors of AE data and the precaution measures taken have been counted in..

3.1 Slump test

The slump test was conducted to find out the concrete performance and workability of the concrete mix. Based on Figure 3, the slump value decreases due to the increase in the percentage of micro steel fiber in the concrete. The highest value is with a percentage of MSF 0% which is normal concrete of 58 and the lowest is with a percentage of MSF 1.25% which is 35. This means the higher the percentage of MSF in the concrete, the lower the value and workability of the concrete.

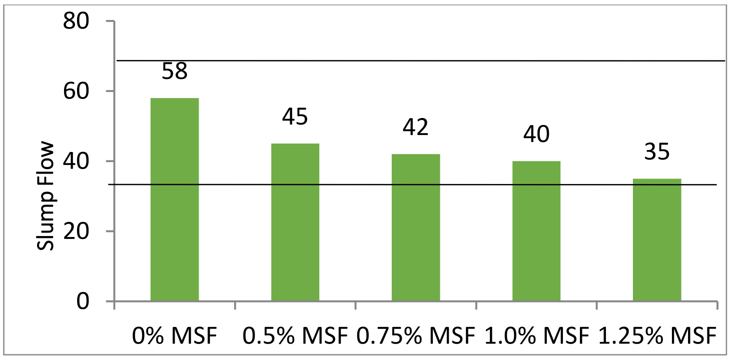


Figure 3: Slump value graph

3.2 Compressive strength test

This test was conducted to indicates the quality of concrete and its id the most important parameter. Figure 4 below shows the compressive strength graph of different percentages of MSF used in concrete. From the graph, it can be concluded that as the content of MSF increases the strength of the concrete composite increases. This proves that, the presence of MSF had enhanced the strength of the concrete. This is possible when the MSF had dispersed evenly within the concrete matrix.

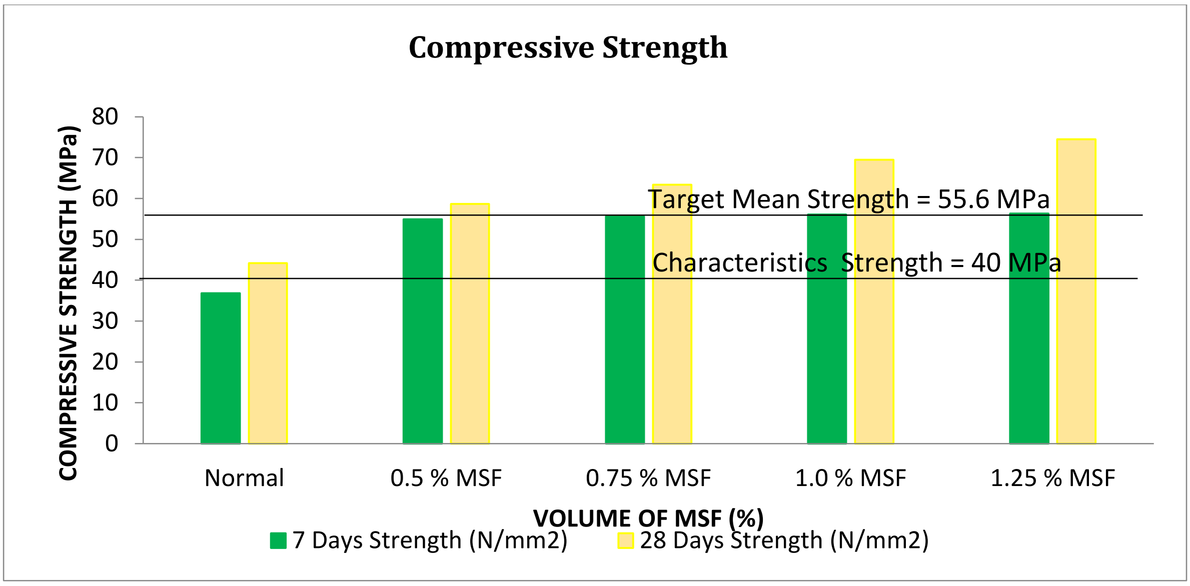


Figure 4: Compressive strength of concrete mix at 7 days and 28 days

3.3 Acoustic Emission Testing

3.3.1 Real Crack Observation

This contains the development of the cracking and breaking process of the beams during the test. All the beams usually have the same pattern of cracks. The micro- crack can be seen during the initial stage of the test at the middle part of the beam. This crack type called a flexural cracking. At the same moment, steel having the tension for exerted form the load of the test.

Even so, the loading increased constant with the normal concrete sample. The flexural type cracks remain to propagate and simultaneously several diagonal cracks were founded between support and loading point. At the same time, the link took shear load and influence the stiffness of the beam. The type of cracks is called as mixed mode cracking that means the combination of tensile and shear. The sample failed when load reached 13.4kN.

The loading remains same but the sample change to 0.5% of MSF. The flexural cracks develop rapidly between point loading to produce a major crack and spread it to the compression area. Besides, the shear cracks started to occur nearly both supports. The sampled failed at 19.82kN load.

Next, the sample was change to 0.75% of MSF with the same loading. The sample of 0.75% took a bit longer to failed, while the flexure cracks remain the same as the loads before. It is called diagonal cracks development for this period. When load reached 20.86kN the sample was failed.

After that the 1.0% of MSF was tested. There was a macro-crack in the middle of the specimen. At the same time, there were 3 to 4 visible cracks found near the support. Both combination of tensile and shear occurs at the sample. For the sample 1.25% it takes the longest time to failed and showed some minor and major crack at the middle. Both samples failed when loading reached 22.18kN and 25.24kN.

Figure 5: 0%, 0.5%, 0.75%, 1.00%, and 1.25% of MSF concrete

3.3.2 b-value

b-value analysis is a method of analysis in AE test. It is about the distribution of the frequency of AE hits with b-value and the cumulative frequency. This method of analysis has been usually used in seismology to describe the earthquake population. In this method, the amplitude of the AE data is the key parameter for detection of the fracture cracking process. The b-value analysis of acoustic emissions commonly got from the grouping the events based on time and number to groups of events (Muralidhara and Eskandari, 2010).

From the graph of the amplitude versus time on every percentage of MSF (0, 0.5, 0.75, 1.0, 1.25) the initiation of micro cracks which later developed to macro cracks till the specimen fractured can be determine. The highest amplitude can be seen at the beginning from 0.5% of Micro Steel Fiber concrete. The highest amplitude can be seen it is in the range of 95dB to 100dB and the value of highest amplitude increased for the next sample. This can be seen at the graph from 0.75% to 1.25%. The higher the amplitude value, proves the presence of macro-cracks on the concrete surface. As the load increases the width of macro-cracks increases until the specimen fracture.

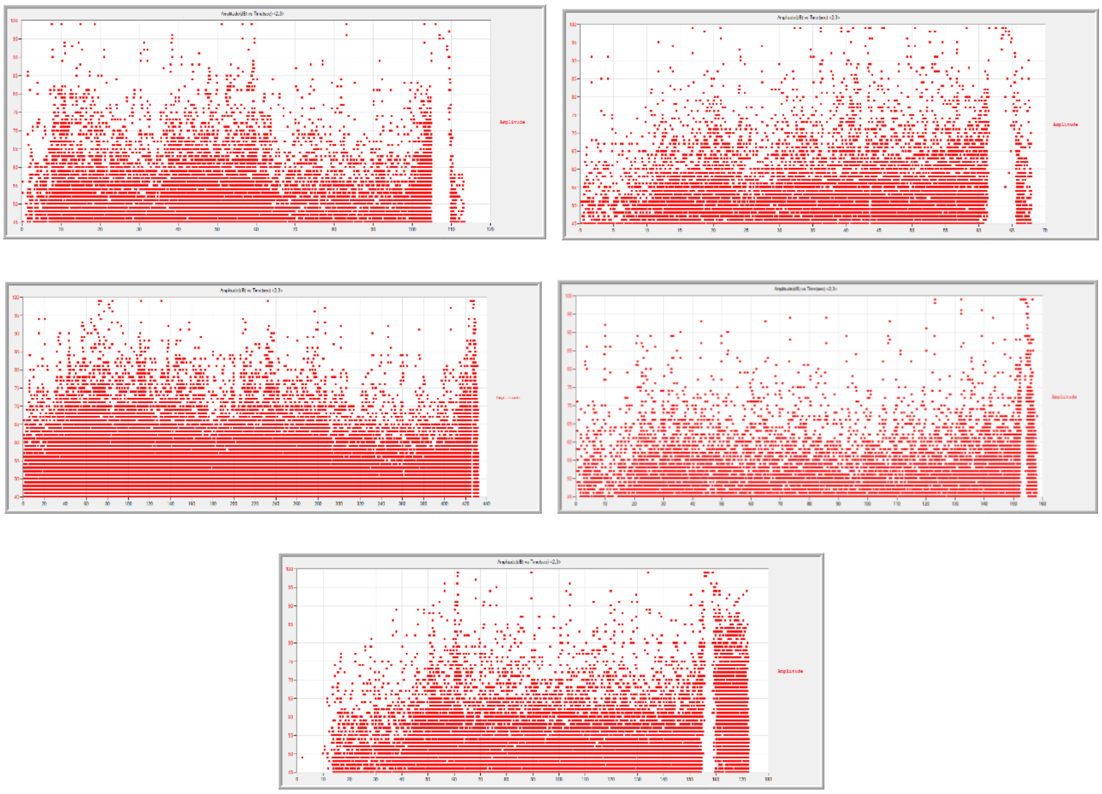
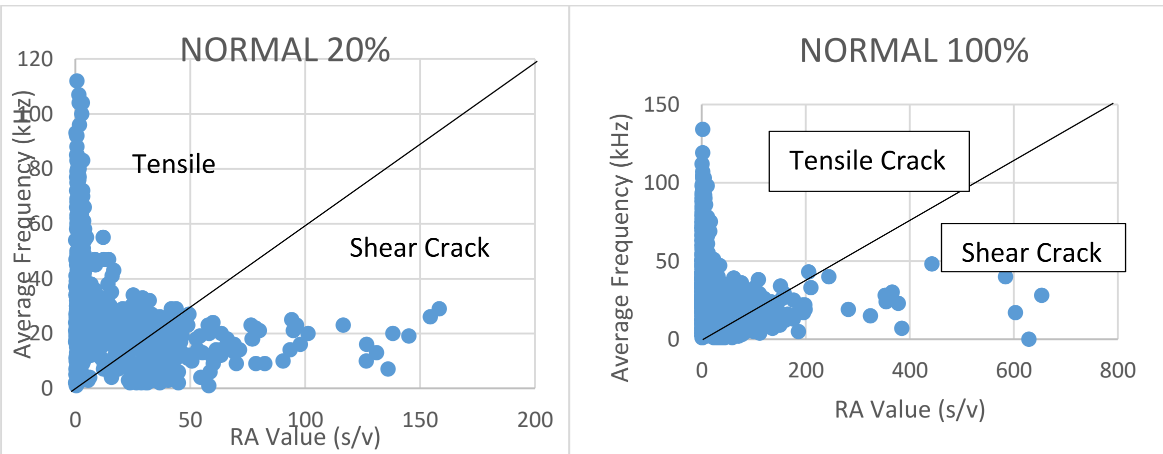


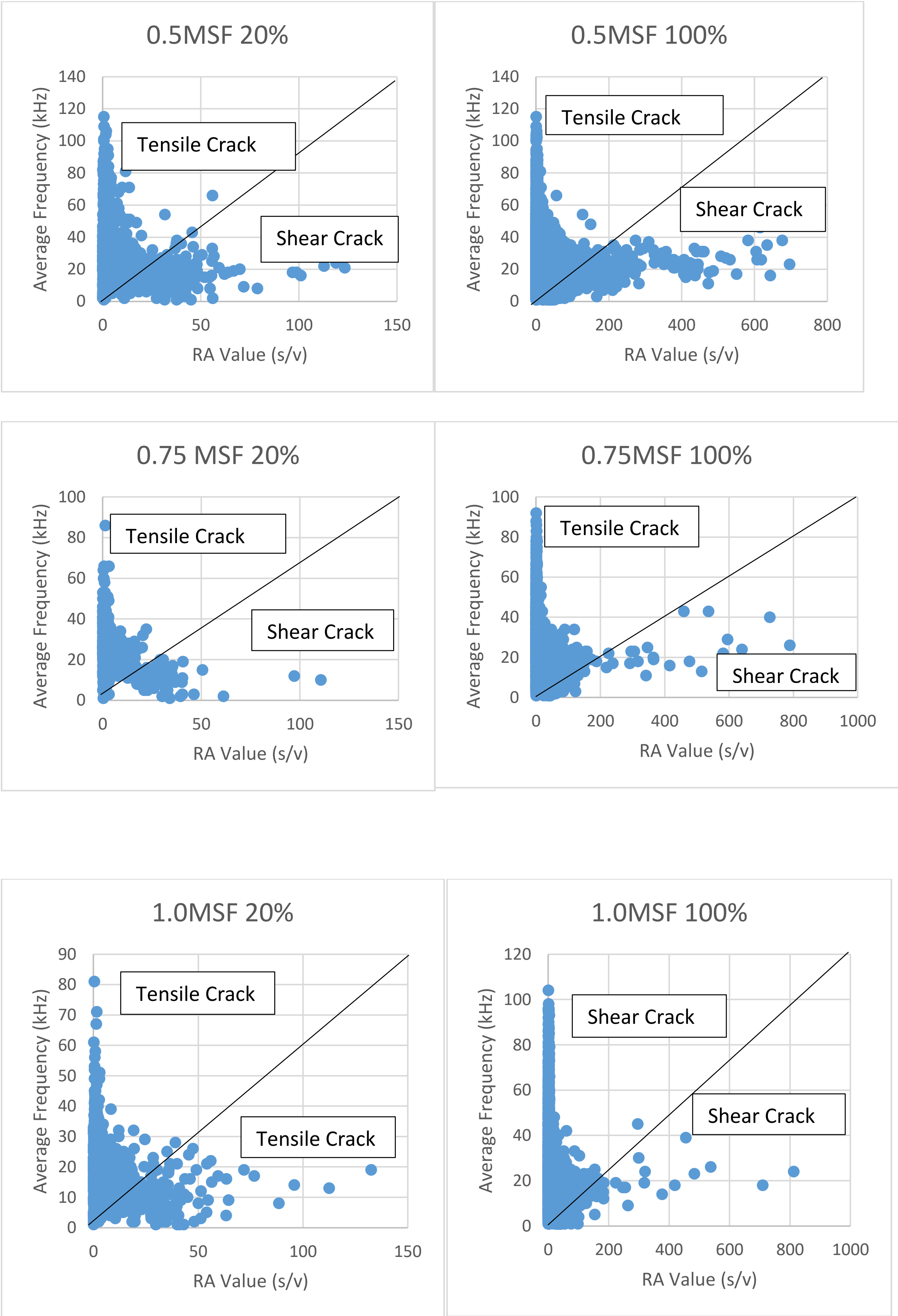
Figure 6: Graph of Amplitude vs Time for concrete with 0%, 0.5%, 0.75%, 1.00% and 1.25% of MSF

3.3.3 RA Value

The cracks of the concrete can be observed during the load test. Acoustic emission signal data collected during the test and observation of the test. Each point of the data presents the location of the acoustic emission signal. The dot color presents the total number of the acoustic emission signal of specific amplitudes location. The ratio analysis conducted based on the zones.

Based on the graph, more crack at the sample occurs at tensile than shear. The crack location for normal concrete looks balanced between tensile crack and shear crack. The pattern for the crack changed start with the 0.5% of concrete. The data have been analyses with 20% to see the initial stage which is micro crack that happen in the middle of the sample. Graph pattern looks same from 0.5% to 1.25% with cracking occurs more to tensile crack.




0.5MSF 20%
Average Frequency (kHz)
RA Value (s/v)
Tensile Crack
Shear Crack
0.5MSF 100%
Average Frequency (kHz)
RA Value (s/v)
Tensile Crack
Shear Crack
0.75 MSF 20%
Average Frequency (kHz)
RA Value (s/v)
Tensile Crack
Shear Crack
0.75MSF 100%
Average Frequency (kHz)
RA Value (s/v)
Tensile Crack
Shear Crack
1.0MSF 20%
Average Frequency (kHz)
RA Value (s/v)
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Shear Crack

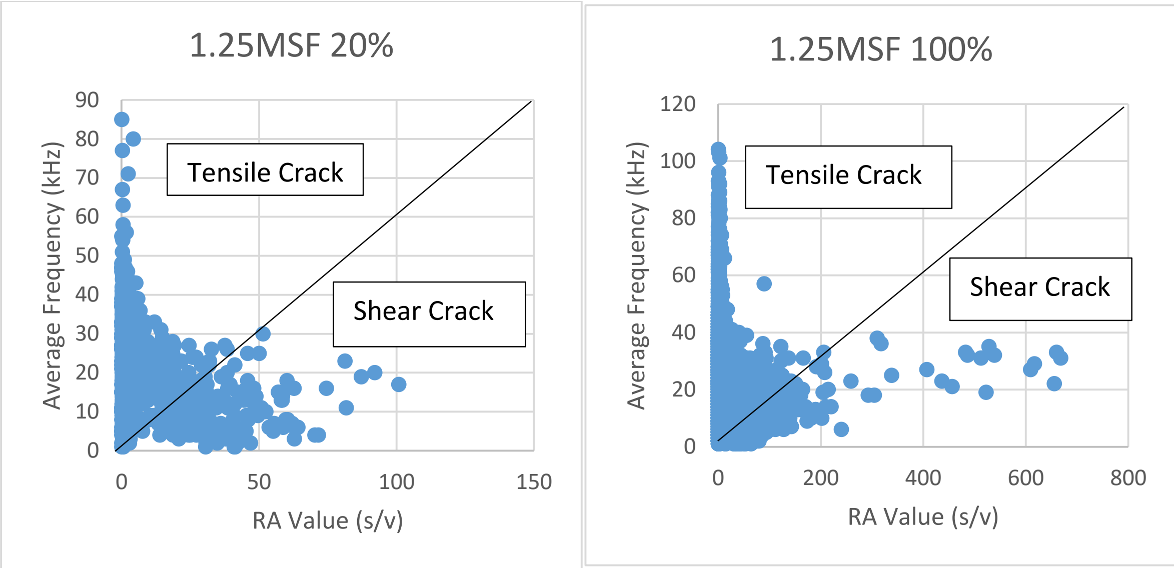

Figure 7: The graph of Average frequency versus RA value for sample (0%, 0.5%, 0.75%, 1.0% and 1.25% MSF)

4. Conclusion

Based on the results of the acoustic emission test in the laboratory and analysis of data generated, the conclusions can be drawn as follows:

4.1 Evaluation of Acoustic Emission Signal

From the graphs generated, the conclusion made were:

i. The histogram graph seems to be same for every sample for the test. The graph of signal strength against time divided into two channels. The normal concrete generate higher signal strength. The signal strength for the concrete with 0.5% MSF to 1.25% MSF decreases. An increment of signal strength show that there is an increment in amplitude during the test. The greater the amplitude value, means that occurrence of macro-cracks.

ii. The graph pattern for energy against time seems to be also similar for each sample. The energy increase from the initial stage until final stage. The concrete specimen with 0.75% MSF and normal concrete gives a low value of energy for the test. This is due to the occurrence of macro-cracks.

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