TO STUDY THE PERFORMANCE OF CONCRETE MADE WITH WASTE MATERIALS USING ACOUSTIC EMISSION TECHNIQUE

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ABSTRACT

Waste Materials that are generated from industries can be treated as a useful resource instead of dumping openly them thus impacting the environment. In order to at least reduce the accumulation of certain kinds of waste, it has been suggested to reuse some of these waste materials to substitute a percentage of the primary materials used in concrete. This study tackles the problem of the waste materials which can be used as replacement of materials in concrete. The study aims at using acoustic emission (AE) technique to study the performance of concrete made with replacement of different waste materials. The study investigates the crack growth behavior of normal concrete and concrete made with replacing different waste materials. Acoustic Emission is one of the important non destructive methods of testing concrete and is different from other non destructive methods of testing concrete. AE technique is used for assessing damage such as initiation and growth of cracks in different concrete specimens subjected to compressive load. It was done by studying the AE parameters resulting from the analysis system. This study was able to define the progression of cracks in concrete from micro to macro- cracks. The AE parameters were able to act as warning before actual failure of concrete occurred. AE technique results aimed at damage assessment and crack monitoring in concrete specimens under compressive load. Acoustic emission can be performed with portable instruments in laboratory. Typically, systems contain a sensor, preamplifier, a data acquisition system and an analysis system. The waste materials considered in this study are fly ash, bottom ash, rice husk ash, crumb rubber & marble waste. The materials chosen were carefully studied with respect to their properties such as fineness modulus, specific gravity, particle size distribution and chemical composition. These all waste materials according to their different physical & chemical properties show different behavior and effect on properties of hardened concrete. Study has been done to compare cracking in normal concrete as well as concrete made with partial replacement of different waste materials using AE parameters.

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CHAPTER - 1 INTRODUCTION

1.1 MOTIVATION & BACKGROUND

Fast development of urbanization and increasing world's population brings greater structures or advancements and a requirement for more individuals to fit in a smaller area. For development and better infrastructure, construction projects are increasing rapidly. As concrete is most widely used in construction, consumption of concrete is on rise. The consumption of concrete is at 2^{nd} place after water and is a standout amongst the most vital materials in building development and other framework. About 10 billion tons of concrete is produced every year. Such quantity requires vast amounts of natural resources for aggregate and cement production seriously impacting the environment. Due to this natural resources are getting depleted in large extent. So it is better to find out new alternative materials for justifiable development by which natural resources consumption will decrease considerably.

On the other hand large amount of waste materials are produced every year through industries which lead to serious disposal issues thus affecting our environment. In order to reduce the collection of waste materials, it has been recommended to reuse some of these waste materials as a replacement of conventional materials to form concrete. Each waste material show different behavior and gives different performance of hardened concrete when replaced. Such behavior and performance concrete made with different waste materials will be studied and understand using acoustic emission monitoring.

1.2 WASTE MATERIALS

Many waste materials can be useful in making concrete which will otherwise be disposed and be useless. It will ultimately decrease the burden falling on natural resources for concrete production. There are different types of waste materials produced in industries which can be used in successful way in making substantial concrete such as slag, silica fume, fly ash, plastic, broken glass, rice husk ash, etc. Many past studies have suggested that various waste materials can be replaced partially or fully with materials such as cement, sand & aggregates from which concrete is made. So instead of dumping a waste material, it can be used in concrete to reduce the environmental problems.

1.3 ACOUSTIC EMISSION TECHNIQUE

Acoustic Emission is a one of the Non Destructive Testing (NDT) methods of testing concrete. The AE technique is already successful in the damage assessment field of structures. In order to record the transient waves sensors are placed properly on the member surface. Transient waves are produced by the crack propagation occurrences inside the material. Eventually, various AE descriptors or parameters are used to characterize the damage level occurred in the member. Transient waves study provides brief understanding of the fracture process. The source of AE activity is closely connected to the fracture mode. After the dominant mode, it becomes easier to reinforce the structure.

1.4 OUTLINE OF REPORT

Chapter - 1 gives a general introduction and outline of this report

Chapter - 2 deals with explanation given on waste materials and gives list of materials with introduction

Chapter - 3 deals with literature work already done on waste materials

Chapter - 4 gives brief description on acoustic emission technique

Chapter - 5 deals with literature review on acoustic emission technique

Chapter - 6 deals with Significance of Research

Chapter - 7 deals with Research Methodology

Chapter - 8 gives list of References

CHAPTER - 2 WASTE MATERIALS

2.1 SOURCE & FORMATION

With an increasing growth in population, the quantity and variety of waste materials have expanded consistently. There are numerous amount of non-decomposing waste materials will remain in the environment for hundred years or more which will ultimately cause a waste disposal crisis, subsequently adding to serious environmental issues. Disposal of waste is a worldwide problem, especially in the thickly populated areas. The majority of these waste materials are left as stockpiles, landfill or illicitly dumped. There are different sources of waste materials from which they are formed which are given as:-

i) Municipal Sources
ii) Medical/Clinical Sources
iii) Agricultural Sources
iv) Industrial Sources
v) Through Construction Sites
vi) Through Automobiles
vii) Through Electronic Products

In our study we mainly focus on waste materials formed through Industries (such as thermal power plants), Agricultural industries, Automobiles & through Construction Industry.

2.2 ENVIRONMENTAL ISSUES & CHALLENGE

Waste Materials in tremendous amount are produced every year through different sources such as Industries, Automobiles, Construction Sites etc and the production of these waste materials keeps on increasing with every year thus having various harmful impacts on the surroundings. Shortage of land and high production of waste materials are leading towards waste disposal problems. Deposits of various waste materials are becoming an ecological threat to the surrounding community. Many waste materials have high content of toxic which when mixed with ground water when percolating through soil due to improper dumping which ultimately causes water contamination. It can be extremely dangerous when ground water is the source of drinking water. Various waste materials when put openly causes respiratory issues. Also many waste materials should not be disposed in landfill because these waste materials cause impacts on carcinogens and ecotoxicity.

There is a massive challenge of proper disposal of waste materials. The high rate of urbanization and population growth has made it difficult to implement effective disposal of waste. Large percentage of waste is left to be illegally dumped. The generated waste is growing at increasing rate and governing authorities could not able to provide adequate disposal mechanisms. It is currently a worldwide worry to find environment friendly solutions for disposing industrial wastes in proper & safer form to maintain a cleaner and healthy environment.

2.3 OVERCOMING THE CHALLENGE

A successful procedure for managing & disposing of waste materials can offer enhanced answers for the various issues related with waste materials. This will further ensure that there is dynamic change of modern and cost-effective facilities which mean to support higher environmental protection levels. With an effective management policy it will also be seen that landfills are situated genuinely to ease waste collection, its transfer, and reusing in proper form. This can be accomplished through the execution of waste disposal plan for which must incorporate appropriate checking and monitoring of waste materials.

A diverse approach on waste transfer and redirection in terms of more hygienic and efficient waste disposal management can offer tremendous solution to waste issues. To address large portion of waste issues, especially landfills, the local authorities and state waste administration offices need to make a detail waste diversion proposals. These proposals are made with a target of verifying that there is helpful and appropriate waste disposal with good waste disposal facilities.

In last but not least usage of the waste materials in producing other needful materials is the main engaging proposal to its disposal. Due to consistently expanding amount of waste materials, utilization of such materials will be really helpful. Research in innovative use of waste materials is continuously proceeding. These efforts in research try to help society’s need for secure and economic waste disposal.

2.4 SCOPE OF USING WASTE MATERIALS TO MAKE CONCRETE

By replacing the waste materials not only moderate diminishing resources but also avoid the natural and environmental harms triggered by quarrying and misuse of the raw materials for concrete production. It will take care of the issue generally experienced in disposal of waste materials to some extent. Replacement with materials that require little processing will decrease release of harmful gases and also reduces consumption of energy. The production of waste materials that can suitably replace cement such as slag, fly ash, rice husk ash etc. is more than twice of cement production. These materials can be partly taken, or processed, to make materials fit for aggregates or fillers in concrete. Such materials can likewise be utilized as clinker raw materials, or handled into cementing systems. Also, new pounding and blending technology will make the utilization of these optional materials more feasible. Many past studies have suggested that waste materials can be partially or fully replace in making of concrete.

Various waste materials which can be useful in making concrete will be otherwise dispose and will be useless. By using waste materials in producing concrete can be genuinely helpful in two ways:-

1. It presents new possible materials for sustainable growth which will significantly decrease the depletion of natural resources which is essential to shield the interests of coming generations.
2. It would be helpful to attain a great step towards acceptable & clean environment.

2.5 WASTE MATERIALS CONSIDERED IN THIS STUDY

If disposal of a material is an expense, one normally considers transforming it into something useful. Instead of disposing such material which will otherwise be useless, it will be a better way to form them in concrete. Interest has been created in using a variety of wastes in this way. There are various waste materials which can be used in making concrete such as slag, fly ash, silica fume, plastic, broken glass, rice husk ash, marble waste etc. In our study the waste materials considered are i) Fly Ash, ii) Bottom Ash, iii) Rice Husk Ash, iv) Crumb Rubber and) v) Marble Waste Powder. The introduction and production of these waste materials is given below:-

i) **Fly Ash -** Fly ash is a finely partitioned residue (a powder looking like cement) that outcomes from the burning of grinded coal in electric power producing plants. Basically, it is the unburned deposit that is moved away from the combustion chamber by the exhaust gases and after that gathered by electrostatic precipitators. The heavier unburned particles fall to the bottom of the combustion chamber known as bottom ash while the lighter ash particles are known as fly ash which will eventually removed away by electrostatic precipitators or bag houses. Fly ash is one the finer material that can be used in concrete. Fly ash consists of particles which are normally spherical, usually vary in size between 10-100 micron . These little glass spheres enhance the ease and workability of fresh concrete. Fly ash's fineness is one of the essential properties adding to the pozzolanic reactivity of it. In concrete industry, Portland cement is one of primary contributor to the environmental trouble and cabon dioxide ejection. Using fly ash which is a supplementary cementing material will help in dealing with environmental issues to some extent. This will also help in tackling the disposal issue of fly ash by partially replacing it with cement to form concrete.

Fig. 2.1: Fly Ash

By pozzolanic activity fly ash helps to form more amount of binder along with hydration of cement in fly ash concrete. This reaction is the chemical reaction that happens between Portland cement and water and results in the arrangement of durable binder, i.e. calcium silicate hydrate gel (CSH) and free lime (nondurable binder). Pozzolanic reaction in plain and fly ash concrete can be represented as follows:-

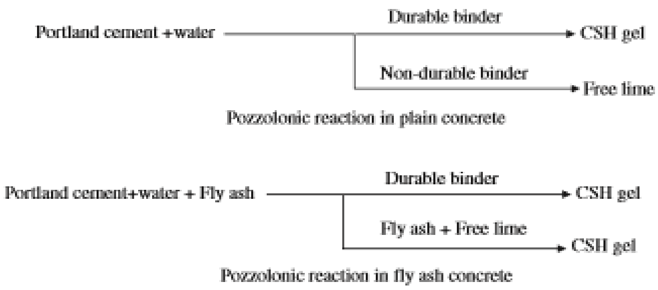

Fig. 2.2: Pozzolanic reaction of plain & fly ash concrete

The formation of CSH gel closes the micropores and plays an important role in the enhancement of fly ash concrete. Pozzolanic reactions are useful for concrete as they exceed the amount of durable binder which is CSH also hydrating calcium aluminate to a marginal extent. This will improve the long term strength and also decreasing the permeability of concrete.

ii) **Bottom Ash -** Burning of tremendous volumes of coal at electricity generating thermal plants brings about generation of coal bottom ash at an expansive scale. In the combustion chamber, carbon and other flammable matter burn while the non-flammable matter produces as coal ash which relies on the non flammable matter present in coal. The ash particles are taken away out of furnace by twisting air movement where finally it cools down. The fumes gases divert the lighter ash particles which are collected by electrostatic precipitators. These lighter ash particles are termed as fly ash. Also, some heavier ash particles which drop down to the base of the furnace are defined as bottom ash.

Fig. 2.3 : Bottom Ash

As per physical properties the image of bottom ash is similar to natural river sand and its particle size varies from 150 microns to 4.75 mm. The properties of bottom ash draws the attention of researchers to explore its utilisation as an alternative material which can be replace with sand in formation of concrete.

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iii) **Rice Husk Ash –** Processing of paddy produces a by-product suitable for use in concrete known as Rice Husk Ash (RHA). As a pozzolanic material it can be replaces with cement to some extent. Burning of rice husk generate about 25 % of rice husk ash containing more than 80 % of amorphous silica and about 5% alumina which is the reason behind its pozzolanic property. Under controlled burning conditions, the ash is produced in temperature upto 700 degree Celsius by incinerating temperature for 1 h which can possibly turns the silica into amorphous phase. The ideal time for burning duration would be 6 hours.

RHA potentially settle the issue of recycling enormous amount of husk waste which will eventually be land filled. RHA is produced in massive amount each year so there is a great scope of reusing this waste material into construction materials

Fig. 2.4 : Rice Husk Ash

which will be an environmental friendly approach for preserving resources. RHA pozzolanic property is due to presence of i) Silica content & its crystallization phase and physical properties such size & surface area. Also rice husk ash must contain little amount cabon content in it. Past investigations demonstrated that concrete with RHA required more water for an ideal uniformity due to its tendency to absorb.

iv) **Crumb Rubber -** There is most likely that the expanding heaps of utilized tires make ecological concerns. As tire waste extend to gather as well as accessibility and room of landfill spaces are decreasing day by day, various organizations are expanding application & utilization of reprocess materials like crumb rubber from waste tires in construction activities. Crumb rubber (CR) is a by-product made by re-processing disposed automobile tires. There are two considerable processes for making crumb rubber which are i) Ambient mechanical grinding & ii) Cryogenic grinding out of which cryogenic grinding process is costly but more finer crumb rubber particles are produced by this process.

Fig. 2.5 : Crumb Rubber

CR is fine rubber particle which can substitute a percentage of the fine aggregate in the concrete mix. Some studies have been done to decide the new and solidified properties of crumb rubber concrete in which the crumb rubber is used to partially replace fine aggregate. Some of these studies examine the useful properties of crumb rubber in resulting concrete such as low density with effective sound absorption, good thermal & impact resistivity and also its toughness.

v) **Marble Waste Powder -** Marble is mechanically prepared by being cut, cleaned, and utilized for decorative, ornamental & construction purposes, and therefore, monetarily significant. Stones are cut as squares or blocks through various techniques during marble quarry process. When cutting of marble is done, about 25 % of marble square or block becomes waste marble powder. In such manner, numerous amount of marble waste from marble industries are produced in the most recent decades and develops altogether in time. The marble waste is mainly a high polluting type of industrial waste due to its highly alkaline which causes critical health risk to the environment.

Fig. 2.6 : Marble Waste Powder

In this way, the utilization of marble waste material in making concrete as an admixture material or aggregate has progressively turned into an essential matter. It was said in past investigations that probability of utilization of marble waste as a material in forming concrete as aggregate influenced emphatically on the hardened properties of concrete which encourages to use marble waste powder as a replacement to fine aggregate in concrete.

CHAPTER - 3 LITERATURE REVIEW ON WASTE MATERIALS

A significant amount of research work on making concrete by replacement of waste has been done by many investigators research area such as

[1] P. Chindap ra sirt et al. (2009) did a combined study with doing comparison between the features of geopolymers of fly ash & bottom ash. Sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) solutions were used as activators with a mass ratio of 1.5 Na2SiO3/NaOH and three concentrations of NaOH (5, 10, and 15 M) were taken; the curing of geopolymers done at 65 °C for 48 h. It is concluded that fly ash and ground bottom ash were appropriate source of materials for creation of geopolymer. It was shown in results higher degree of geopolymerization had been achieved by fly ash which is additionally reactive with respect to bottom ash which were shown from FT-IR, DSC thermo gram, SEM, and XRD methods of analyses.

[2] R. Madandoust (2011) did a study the outcomes of using rice husk ash (RHA) on mechanical properties of concrete and also on its durability. Establishing a proper amount of rice husk ash for replacing partially replacing it with cement in concrete was done, 0-30 % of RHA was replaced. Also the mechanical properties determined. Durability studies with compressive strength test with chloride test analysis had been performed. The results showing improved durability with negligible increase in early age compressive strength but at later age higher compressive strength had been told. (SEM) scanning electroscope microscopy had also been done of samples showing about the pore structure of RHA which defined the superiority of mortar with RHA performance mechanically.

[3] B.S. Mohammed et al. (2012) studied the progress of hollow concrete block made with crumb rubber explaining the performance in the characteristics of crumb rubber hollow concrete block in which replacement of crumb rubber with fine aggregates was done. The main objective for which this research work was done in improving acoustic, thermal and electrical aspects of the crumb rubber hollow concrete block by partial replacement of crumb rubber with fine aggregates. Addition of fly ash and silica fume was done for improving strength. 64 trial mixes were prepared to produce hollow concrete blocks made with crumb rubber of dimension 390 mm x190 mm x190 mm. The varied replacement percentages of crumb rubber with fine aggregates are 0%, 10%, 25% & 50%.

Tests organized on hardened concrete were compressive strength test along with thermal conductivity, electrical resistivity & acoustic absorption. Main outcomes from this study were CRHCB could be produced as replacing 6.5% of crumb rubber was ideal for load-bearing hollow concrete block and replacing 40.7% of crumb rubber was appropriate for non load-bearing hollow concrete block. CRHCB had lower thermal conductivity, better sound absorption with better noise reduction factor and also had higher electrical resistivity than conventional hollow concrete block.

[4] R. Siddique et al. (2012) examined the water/powder ratio effect on strength properties of self-compacting concrete containing coal bottom and fly ash. Fly ash replaced with cement in percentages varying from 15-35 % and bottom ash would be replaced with sand with varying percentages of 0%, 10%, 20% & 30%. At Various mixes for testing strength were taken out at the ages of 28, 90 and 365 days respectively. The ideal fly ash percentage was 25–35% and bottom ash was up to 20%. Making self compacting concrete of 40–50 MPa compressive strength in which fly ash replacement was 15–35% was feasible. The bottom ash could be used up to 20% keeping in view the decrease of strength of about 15–20%. Some percentages of Fly ash which were 15% and 20% were not considered, as they showed greater reduction in strength. Therefore, the ideal fly ash percentage was 25–35% and bottom ash percentage was up to 20% in this research. Based on the materials utilized as a part of this investigation, the outcomes proposed that it was in fact possible to use bottom ash as a part of paste content in the generation of self compacting concrete.

[5] P. Sukontasukkul, K. Tiamlom (2012) investigated rubberized concrete enlargement under water and drying shrinkage which used in pre-cast lightweight panels. In mix proportions crumb rubber was replaced with fine aggregate in varying percentages. Experiments which were performed were for testing compression, expansion, absorption and shrinkage. For this two different sizes of crumb rubber were used. It was noted that non-polar effect was there in large crumb rubber where the non –polar effect became insignificant in smaller crumb rubber. Large crumb rubber expanded higher than smaller one. In case of shrinkage smaller size CR found to show excessive shrinkage than larger one. Utilizing smaller size CR particles had indicated a significant one of a kind impact in the properties of rubberized concrete which enabled the concrete to had a lower absorption and expansion (which was very inverse to most lightweight concrete). But, there was likewise a downside as a result of its low compressive strength and elastic modulus.

[6] C.A. Issa, G. Salem (2013) attempted the study of utilizing recycled crumb rubber as a replacement to fine aggregates in concrete mix design. This study showed that crumb rubber which was recycled could be used as useful replacement for fine aggregates. 0-100 % replacement of crumb rubber with crushed sand in concrete mixes was investigated. Based on this research some points were concluded. Increase in compressive strength when rubber content was lower than 25 % but beyond this percentage compressive strength drops enormously. At 25% rubber replacement with sand, decrease in density about 8 % was reported. Also improved insulation and dampening properties were noted. The drawback was uncertain failure of CR because stress vs. strain did not followed fixed pattern in experimental observation at same point.

[7] M. Singh, R. Siddique (2015) described the characteristics of concrete carrying high volume of coal bottom ash. Researcher said about use of bottom ash for sustainability of natural resources. Replacing natural sand with bottom ash could prove technically and monetarily useful to the construction development. River sand was substituted with coal bottom ash by mass in concrete from 0-100% replacement level. the test outcomes reveal that 28 days compressive strength and pulse velocity from concrete were not influenced on utilizing coal bottom ash in concrete. Initial rate of absorbing water by capillary activity expanded on including bottom ash in concrete. Yet, the auxiliary rate of absorption of water was consistent for all concrete mix. The absorption of water changed in the vicinity 4.68 and 5.56% for every single concrete mix at curing period of 28 days. Bottom ash concrete mix showed extremely lesser resistance to abrasion than standard concrete. Up to 50% substitution of sand, there was no considerable decrease in compressive strength. With 100% coal bottom ash compressive strength brought down to 15.16% than standard concrete. With further advancement in curing period, considerable increase in compressive strength of bottom ash concrete mix was watched.

[8] Gulden Cagin Ulubeyli and Recep Artir (2015) explained effective usage of marble waste power by using it in making concrete. Properties effected by using marble waste powder in making concrete had been discussed. Many different usage of marble waste powder was discussed such as using it as binder in cement or marble waste used as aggregate with various sizes opening in polymer concrete mix but usual usage of marble waste powder was noted to use as replacement of fine aggregates in concrete and it was examined in detailed manner.

Hardened concrete characteristics was decidedly influenced by utilizing waste marble binder or aggregate in the standard concrete.

[9] M. Rafieizonooz et al. (2016) investigated about use of coal bottom ash and fly ash together as replacing sand and cement in concrete. Using such waste which is otherwise sent to dumping is an environment friendly option. The samples of concrete were prepared replacing 0% 20%, 50%, 75% and 100% of bottom ash with sand and 20% of fly ash as a replacement for Ordinary Portland cement. Results revealed that workability of concrete was reduced when bottom ash content exceeded. No early age compressive, tensile & flexural strength was observed. At later ages about 91 & 180 days, compressive strength of all mixes i.e. experimental and control concrete were identical. But, flexure and split tensile strengths of the concrete mix holding 75% bottom ash and 20% fly ash surpassed significantly more than the standard test. The drying shrinkage of concrete was lower than standard mixture when containing 50%, 75% and 100% bottom ash and 20% fly ash.

[10] R. Siddique et al. (2016) presented in this paper about the impact of bacterial content on the mechanical attributes of concrete made with rice husk ash. Concrete prepared in control manner was represented to have 28 days compressive strength of 32.8 MPa. Cement was partially substituted with 0, 5, 10, 15 and 20% by weight of RHA. After this bacterium Bacillus aerius (105 cells/mL) was mixed in water during making of concrete. It was noted that inclusion of bacteria in RHA concrete improved its compressive strength at all ages. But, optimum performance was attained when replacing RHA with 10% where 28 days of compressive strength was 36.1 MPa. and with bacteria, it was 40.0 MPa. Incorporating the bacterial content in RHA concrete decreased its water absorption and permeability at all ages, because of calcite content in it, which successively upgrades all these properties. SEM and XRD further examine the formation of (CSH) and calcite which made the concrete denser.

[11] Zhi-hai He (2017) presented an observational research on the mechanical traits of concrete made with replacement of rice husk ash which act as supplementary cementing material (SCM). Different RHA contents were taken for concrete specimens. The contents taken were 0%, 10%, 15% & 20%. Results of compressive strength, modulus of elasticity and creep were acquired by proper examination from samples. It was observed that the increment of RHA in concrete can refine the compressive strength and modulus of elasticity and decrease the creep of concrete. The particles RHA at early ages can enhance hydration of cement and in this manner decrease the porosity identified with gel pores. The creep strain diminishes with the expansion of RHA added in concrete. But, identical to the expansion of modulus of elasticity, the reduction of creep strain with increased RHA was only up to a certain level of RHA.

CHAPTER - 4 ACOUSTIC EMISSION TECHNIQUE

4.1 DESCRIPTION & PRINCIPLE

Acoustic Emission (AE) refers to the generation of transient elastic waves created by a sudden redistribution of stress in a material. The source of acoustic emission wave is the redistribution of the stress inside the material due to movement of some kind of defect which could be crack which can initiate and then propagate. Due to crack propagation there will be a movement on an atomic scale due to which elastic waves will be generated which can be detected by sensors. Hence there could be some defect which is active inside the specimen.

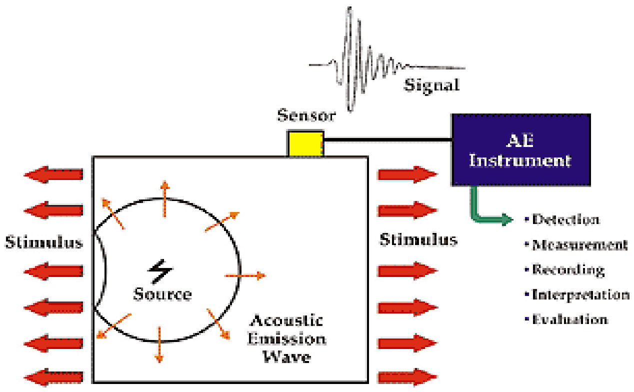


Fig. 4.1 : AE Source & Instrument

When analysing the material using AE technique load is the main requirement. When loading is there after which some movement will be there and hence initiation of cracks occur which can generate the elastic waves. So the system which is to be examined must be loaded. If there is no load then there will be no emission. So the crack developed need to be active for detection. Monitoring of big structures can also be done by acoustic emission by placing the sensors at different location of the structure where the initiation and development of crack might occur. Acoustic Emission is not at all like most other nondestructive testing (NDT) methods in two respects:-

i) The main contrast relates to the source of the signal. Rather than providing energy to the object under examination, AE essentially listens for the energy discharged by the object. AE tests are regularly performed on structures while in activity, as this gives sufficient loading for propagating defect.

ii) AE deals with dynamic processes, or changes, in a material. This is particularly meaningful because only active features (e.g. crack growth) are highlighted. The ability to recognize between developing and stationary defects is significant. AE testing usually provides an immediate indication relating to the strength or risk of failure of a component.

4.2 ACOUSTIC EMISION TESTING PROCESS

Testing process of Acoustic Emission include following processes:-

a) AE Signals detection– As cracks develops, number of waves are released. When AE wave arrives at the surface of sample, little developments of the surface molecules occur. The capacity of AE sensors is to identify this development and change over it into useable electric signal.
b) AE signals process– The little voltage produced by the sensor is intensified and the radio recurrence signal changed to PC. The RF signal is part into discrete waveforms which at that point recommended by attributes, for example, amplitude, rise time, absolute energy based on a user defined threshold.
c) AE Signals display– The gathered waveform can be shown in two different ways which are an) element of waveform parameters and b) as the gathered waveform itself. Most AE tests presently just record the waveform parameters and disregard the gathered waveform which is basically because of the extensive measure of processing memory it employments.
d) AE Signals location– The computerized source area capacity of AE is maybe its most noteworthy fascination as a non damaging strategy. The transcendent technique for source area depends on the estimation of time distinction between the entry of individual AE signals at various sensors in an exhibit.

4.3 HEALTH MONITORING OF CONCRETE STRUCTURES

As cracks in concrete expand, strain energy is released which then is detected with the use of sensors to investigate the cracking phenomenon. The use of such sensors to detect cracking phenomenon in concrete by detecting the released strain energy is the principle of acoustic emission technique. AE technique has found extensive use in health monitoring of structures because this technique is able to locate the crack positions while they are still expanding and this technique can be applied to structures without causing any hindrance to their performance. AE activities consist of primary as well as secondary activities. Crack growth and formation is considered in primary activity while friction between crack surfaces when crack propagation has stopped is considered in secondary activity. Concrete cracking study with the help of AE can be divided into two modes. Mode 1 being the tensile type and mode 2 being the shear type. As cracking starts in concrete and it propagates the flexural behaviour of concrete changes from tensile type to shear type. So to study this change in behaviour while crack expansion, AE technique utilize two modes of cracking. The mode 1 activities are recorded in earlier stages of crack formation as it is the stable stage and mode 2 type cracking activities are recorded when concrete is on the verge to fail. Most of the AE activities are recorded in the unloading process.

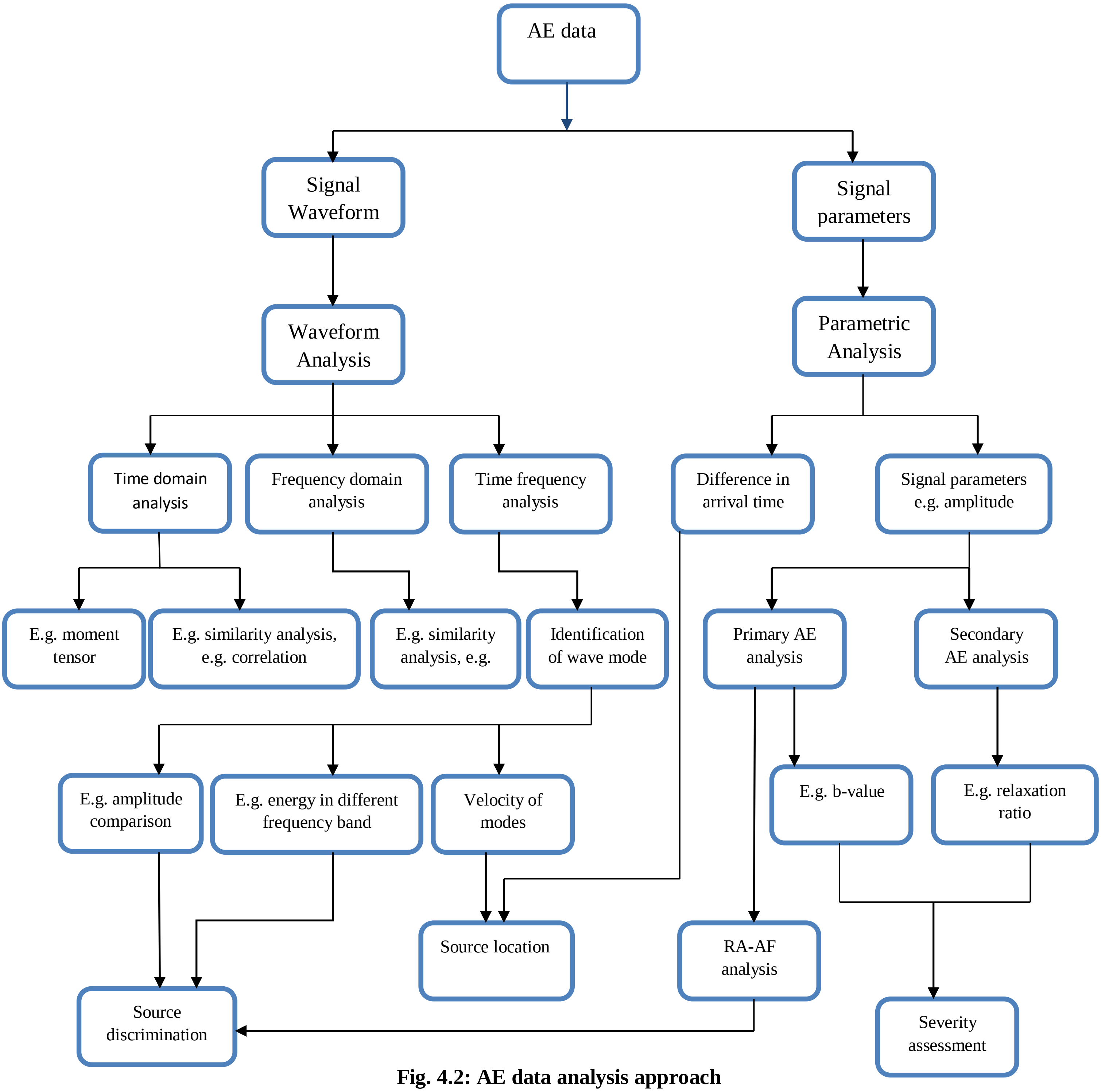


Fig. 4.2: AE data analysis approach

4.4 POTENTIAL STRUCTURAL ASSESSMENT APPROACHES

AE application has been divided into two categories (i) application of AE to assess global health monitoring of structures which includes overall damage assessment of structure and (ii) application of AE to assess local health monitoring of structures which includes monitoring of crack growth or corrosion in concrete. AE data is recorded in two forms, which are waveform and parametric data. So basically AE technique has two approaches which can be followed to analyze a structure. First being parametric approach and second being signal based approach. These two approaches can be used on any of the above discussed categories of AE application i.e. global or local health monitoring of structure.

4.4.1 Parametric Analysis

It is practically impossible to record huge amount of AE activities over a short period of time in the form of signal waveforms. But with parametric analysis the AE signals can be characterised by series of parameters. The extent of damage and its nature can be studied using parameter based approach. So when it comes about feasibility parametric approach stands tall.

4.4.2 Signal Waveform Analysis

As mentioned above only few signal parameters of AE are possible to record while monitoring but it is not possible to record the signal itself. As the amount of data in the process is minimized quick data processing can be achieved. But with advancement in computational processing and sensors it is possible to record multichannel raw waveforms. This approach is useful in discrimination of signal noises which results in better interpretation of data in selected cases.

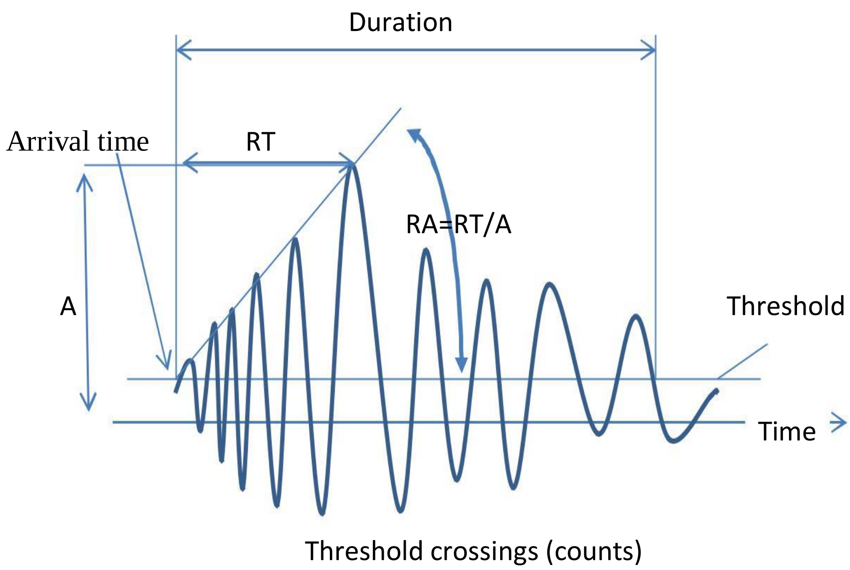


Fig. : 4.3 Parameters related to AE waveform

4.5 TYPES OF AE SENSORS

The AE sensor being used for any analysis should be very reliable as it is the most important component of the AE analysis. The selection of suitable AE sensor depends on the specific application. The elastic waves released from concrete carry mechanical energy which is then changed into electrical signal by the AE sensors, so it is better to term AE sensors as transducers. Piezoelectric transducers are most often used in AE application. The types of sensors can be divided into two categories, resonance and broadband sensors. These sensors find specific suitability for their application depending upon the method of analysis. The sensitivity of resonance sensors is at its peak at resonance frequency. The factor which decides that which AE sensor is to applied is resonance frequency. Resonant AE sensors are applied in cases where AE parameters such as energy, amplitude, arrival time are of more consideration than the frequency content. Resonant sensors are not appropriate to detect displacement. They have high sensitivity towards surface waves but the output signals are unable to estimate real surface wave. For detection of displacement, broadband sensors are found suitable as they have the capability to respond at uniform rate to huge range of the wave's frequency constituents having same responsiveness.

4.6 DAMAGE LOCALISATION PROCESS

For obtaining the source co-ordinates of the AE events, damage localization technique is required. In order to locate the source, the difference in time of arrival of transient waves released during cracking should be calculated inversely. Origin time and the position of source in Cartesian coordinates (x,y,z) are the defining parameters for source location of AE events.

One-D approach

The zone location method is the easiest way for locating the AE source for a 1-dimensional structure. Large structures such as pipes and buildings are often monitored using this method. In this method the sensors are placed in such a way that they either cover wide area for analysis or especially focus on the major locations. After recording of AE events the technician should focus on the source that has been located for cracks or leaks.

Two-D approach

The source location in 2 dimensional structures is achieved by using planar localization technique. The structures with small thickness as compared to its length are monitored using this technique. Only 3 sensors are needed for source location as there are only 3 unknowns (origin time, two coordinates).

Three- D approach

The principle of 3-D localization methods is similar to the principle applied in earthquake hypocenter determination in seismology. It requires four travel times to solve a 3-d localization problem, three travel times for 3 co-ordinates and one for the event source time.

Common method adopted for 3-D localization is noting the arrival time of longitudinal and shear waves. The first arrival time of transient waves which is recorded at each sensor corresponds to the longitudinal (P) waves as they travel faster than the shear(S) waves. If the onset of S waves is also detected, then it is used either in combination with onset of P waves or in place of P waves. If the distance between source and receiver is less, then it becomes quite difficult to identify S-wave.

4.7 AE PARAMETERS

When cracks propagate in concrete they release some energy which in the form of transient waves or hits is absorbed by the sensors placed on the surface of concrete. Then the damage level and cracking phenomenon is characterised using various AE parameters. Failure in concrete occurs in different stages such as matrix cracking, aggregate and cement paste detachment and fiber breakage or pull-out. So for all these stages there are different AE parameters which characterise these failures and help in studying them in a better way. These parameters arise from distinct waveforms or AE signals emitted by distinct failure mechanisms. The level of threshold controlled by the user is one of the main characteristics of AE testing as it should be set at a level that the weak electrical and ambient noises are ignored while the low levels of cracking signals are recorded. Some other basic parameters involved in AE technique include arrival time also known as onset, amplitude, duration, counts, rise time and rise angle. It is to be noted that more is the crack opening displacement more energetic are the waves emitted. The amplitude parameter taken to the scale of cracking as the energy released by the source is directly proportional to the crack width. The rise angle and average frequency correspond to the type of cracking which can be tensile or shear.

AE hits: The incoming transient waves or hits are recorded by sensors. These hits are of primary importance as we get to know about the extent of cracking through these number of hits. For marginal cracking there will be low number of hits and for severe cracking the recorded number of hits would be more. So these recorded hits while application of load are of utmost importance as they give a general idea about the extent of cracking in concrete.

Ib-value: As we know different types of acoustic emission signals are generated by different types of fracture modes so micro cracks emit signals having small amplitude but large number of events and macro cracks emit signals of high amplitude but are less in number. The ratio of weak events to strong events is known as Ib-value. So the Ib-value for micro-cracks is higher than the Ib-value for macro-cracks. With the increase in stress levels as the cracks propagate from micro to macro stage the Ib value graph shows a decreasing trend. This trend can be directly related to the level of stress accumulation due to propagating rupture.

Average frequency (AF): AF is a parameter corresponding to failure mode. It distinguishes between tensile mode of cracking and shear mode of cracking. The signals produced from cracks resembling tensile mode are of relatively high frequency than the signals produced from cracks resembling shear mode. So the increasing or decreasing trend of AF can be related to the shift in failure mode of concrete.

RA value: RA value parameter is also related to damage type. With the accumulation of damage the RA value shifts to the higher values due to transition of cracking mode from tensile to shear. The rise in RA value can be simplified by wave characteristics elevated by different types of cracks. Tensile cracks produce longitudinal waves of high amplitude which reach faster hence resulting in less rise time. In case of shear cracks the shear waves excited are on a slower side as compared to longitudinal waves, leading to longer rise time.

4.8 PRACTICAL APPLICATION OF AE TECHNIQUE

Researchers have monitored historical masonry buildings using acoustic emission. The masonry building being in service condition was assessed for damage and cracking using a particular AE approach. This method made it possible estimating the amount of energy released during crack propagation. For prediction of damage evolution, a fractal dimension methodology was developed which also studied the time taken by structure to collapse. It linked the concepts of fracture mechanics to AE for a damage induced structure. Cardiff University studied a composite 300 m span box girder bridge located in south wales. AE technique is one of the best choice for structural health monitoring in the civil engineering department of University Science of Malaysia, where AE testing has been used as a NDT method to monitor damage in structures. The locations of cracks were predicted with precision. AE-win software was used to perform data analysis for detecting cracks within the structure.

4.9 RECENT TRENDS AND MODERN AE RESEARCH

The recent time application of AE technique, for health monitoring of concrete structures by researchers is divided into four categories, which are explained in the following subsections:

4.9.1 Application Of AE Technique In Corrosion Monitoring

The corrosion induced in RC structures due to the reinforcement steel bars, is studied using AE technique. The AE events and parameters are affected by corrosion in steel bars. It is noted that with the increase in degree of corrosion, the recorded AE events show a drop. Hence the damage level caused to RC structure due to corrosion could easily be studied by AE technique. This technique was also applied to recognize corrosion in pre-stress concrete bridges. It was realised that failure of steel bars and wires of steel, produced high amplitude AE events. Various works have depicted the corrosion triggering time, as well as the early recognition of corrosion in various structures such as pre stress and SCC.

4.9.2 Fatigue Analysis By AE Technique

AE technique has found wide application in fatigue analysis and life span foretelling of concrete structures. Researchers understood relation between the phase of loading and AE activity, which in turn helped evaluating the last stages of damage process by detection of AE events generated close to the minimum phase of loading. It was also observed that when steel reinforcement undergoes plastic deformation, it results in increase in AE activities. The improved b- value parameter depicts that macroscopic fracture phenomenon commonly takes place during the paths of loading.

4.9.3 AE Technique Analysis Of Creep Effect

Micro cracking phenomenon and creep effects investigation is carried out using AE technique. A case study has been conducted by Rossi et al. which studied the physical mechanism of basic creep defect of concrete using AE technique. It has been found that during formation of micro cracks resulting from creep effect, water transfer is generated which in turn causes additional shrinkage due to self drying.

CHAPTER - 5 LITERATURE REVIEW ON AE TECHNIQUE

A significant amount of research work on damage assessment of concrete using AI technique has been done by various researchers. Some of the works are presented here

[1] Aggelis et al.[2011] studied the identification of the fracture process in fibre reinforced concrete using acoustic emission technique. Beam specimens of 100 x 100 x 400 mm in size were used to monitor fracture with AE setup. Two AE broadband sensors were attached to the bottom tensile side of the specimen. The fibers used were steel fibers at volume fraction of 1% and aspect ratio 33.33. The failure pattern in the specimens was opposite to that of concrete reinforced with metal bars. Cracks developed at the center extending from the bottom tensile side to the top which is opposite to diagonal cracking in concrete reinforced with metal bars. The Ib-value decreased consistently earlier than 80% of the fracture load. The decrease in Ib value even before the decrease in fracture load, serves the purpose of warning of concrete failure.

It was also noted that load drops by several kN once the first major crack develops. The minimum of Ib-value is achieved at the time of fracture and such action is very crucial for remote monitoring of structures.

[2] Shaowei et al. (2013) studied the concrete fracture procedure based on acoustic emission parameters. The specimens tested were of M25 and M30 grade with 10 samples each with respective beam size as (1100 x 300 x 300) mm and (1000 x 200 x 120) mm. Various parameters associated with crack propagation were evaluated on the basis of three point bending beam tests with the help of acoustic emission set up and strain gauges. Along with the crack propagation the initial and final fracture loads were also monitored. This study divided the cracking phenomenon into 3 stages (i) micro-cracking generation (ii) macro cracking progression (iii) final failure cracking. This study confirmed that AE set up could be very useful for monitoring cracking defects in concrete during loading process. During the process of loading even before the crack generation few parameters such as rising time, impact number and accumulative energy showed slight increase and during the crack propagation and final failure there was an expected increase.

[3] Goszczynska (2013) analyses the process of crack development and further growth in concrete by acoustic emission technique. This could be analysed using destructive process as source of acoustic emission. When the structure was under service load the AE signals then generated were compared with previously created database and then the active deterioration processes were identified. The location of damage or cracking was located using the principle of time difference taken by AE signals to reach the sensors with known wave velocity.

As cracking in concrete starts even when it is unloaded at maturing stage, so the application of acoustic emission was used at both loaded and unloaded stages. The study revealed that using AE technique it was possible not only to locate micro-cracks but also their growth into macro-cracking stage.

[4] Haneef et al. (2013) uses acoustic emission technique to study the cracking behaviour in concrete after addition of fly ash. Curing influence was also studied with the help of acoustic emission technique. Acoustic sensors were placed on plain and fly-ash concrete cube samples of dimension (150x150x150) mm and uniaxial compression testing was performed. AE activity generated 3 defined phase of cracking phenomenon in both concretes (i) micro-cracking (ii) steady crack growth (iii) unstable crack growth. Amplitude decreased through beginning stage of loading with curing for both the types of concrete. Cracking phenomenon in plain and fly ash concrete was compared with the help of AE parameters and were co-related to SEM technique.

[5] A. Behnia et al (2014) explained about two techniques, one is acoustic emission (AE) technique and other is travel time tomography (TTT) technique. These are encouraging elastic waves-based detection methods for condition appraisal of structures. The study was done with a main purpose to scan and access the fracture behaviour of fibre reinforced concrete beams through integrated measurements by AE and TTT tests. Three various types of beam samples were taken, such as plain reinforced concrete (PRC) as the control, steel fibre reinforced concrete (SFRC) and polypropylene fibre reinforced concrete (PFRC) samples. The inside damage caused would be conceptualized at particular load steps using the TTT procedure although constant checking of cracking procedure was directed utilizing AE strategy all through the loading period to gather information for describing the fracture

[6] Q. Han et al. (2018) utilized four typical investigation methods, including the b-value method, AE signal intensity, average frequency(AF) versus RA (RA means rise time divided by the amplitude) value, and cluster analyses, to inspect and explain the damage mechanisms and also the collapse modes of three-point and four-point crumb rubber concrete beams with different rubber percentages which are 0, 5, 10, and 15%. Experiments outcomes show that crumb rubber concrete's fracture magnitude is considerably large than that in the normal concrete before the main failure stage. The enhanced b-value (Ib-value) fluctuations in local regions were more closely clustered with increasing the rubber content. Intensity analyses were based on the plot of historical index(HI) and severity(log10 Sr). Based on the peaks and sudden increment of these two lists, it can be inferred that more macro-cracks with greater signal strengths were made with the expansion of the rubber content of the samples. Six AE parameters were used for cluster analysis.

The commonly partitions for clusters were calculated using the k-means algorithm. The failure modes due to crack development of the crumb rubber concrete were investigated based on the RA and AF values .When the load expand, the type of cracks changed from tensile cracks to shear cracks. Besides, bigger indent profundity samples had lesser tensile cracks previously and shear cracks after the crack. For all samples in the three-point and four-point bending tests, there was a reasonable difference between the different clusters based on the RA and AF values. Besides, the crack procedure can be described by the different clusters dependably utilizing AF, RA, and energy, which are checked non-ruinously.

CHAPTER - 6 SIGNIFICANCE OF RESEARCH

6.1 OBJECTIVE

The prime objective of this study is to examine the performance of various waste materials in mechanical properties of concrete. This has to be done by performing tests such as Compressive strength tests and further monitoring it with acoustic emission (AE) technique. This work focuses at using (AE) technique to study the different type of activity in concrete made with different waste materials. The study investigates the crack growth behavior and type of cracking of concrete made with replacing different waste materials by using AE technique and analysing them.

6.2 SCOPE OF STUDY

There is a vast scope in this study because more research is needed to be done in analyzing various waste materials when replaced in concrete by using acoustic emission technique. This technique is not very much used for analyzing mechanical properties of concrete made by using various waste materials. By considering various waste materials, effort has been done for finding more alternative for replacing materials in concrete.

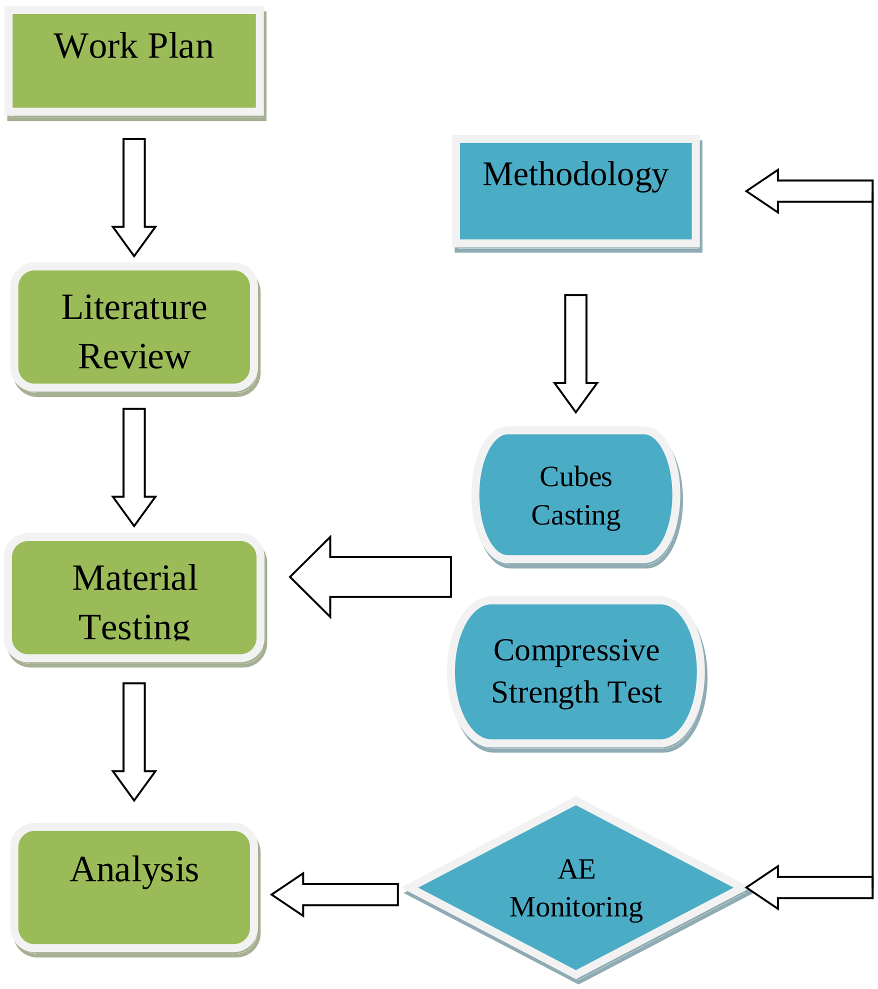
6.3 RESEARCH GAP

From the literature review, it is obvious that the behavior of concrete made using waste materials (fly ash, bottom ash, rice husk ash, crumb rubber & marble waste powder) have been studied using standard methods of testing such as Compressive strength test…etc. However, very less work has been reported on evaluating the behavior of these waste materials on concrete using nondestructive testing techniques like Acoustic emission (AE).

CHAPTER - 7 RESEARCH METHODOLOGY

7.1 METHODS TO USE

The primary motive of this experimental research was to investigate the performance of concrete made with different types waste materials which have different physical and chemical properties. This can be accomplished using standards methods of testing such as compressive strength test and also investigate the suitability of Acoustic emission technique to monitor cracking the specimen. Hence the experimental work in this study is a combination of destructive as well as non-destructive technique. The waste materials considered for replacement are fly ash, bottom ash, rice husk ash, crumb rubber & marble waste powder. Concrete specimens of all these materials will be casted for compressive test and analysing the differences with acoustic emission technique. Research Methodology has been represented in a form of flow chart which is given as



Fig, 7.1: Research Methodology Flow Chart

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