CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

"Conservation is the action taken to prevent decay. It embraces all acts that prolong the life of our cultural and natural heritage, the object being to present to those who use and look at historic buildings with wonder the artistic and human messages that such buildings possess. The minimum effective action is always the best; if possible, the action should be reversible and not prejudice possible future interventions" (Fielden 1982).

The conservation of the cultural property of a country includes anything related with the country’s heritage; it can be a building or groups of buildings on a massive scale or it can even be a tiny artefact. This study focuses on the conservation of sandstone monuments and therefore the literature review concentrates on the conservation of built heritage. Conservation of movable objects like museum objects, artefacts are not dealt with in this literature review.

This chapter covers a review of literature on the conservation of monuments and different research works done on stone conservation at the international and national levels.
2.2 CONSERVATION OF MONUMENTS

2.2.1 Conservation of Monuments – International


Of particular importance is the “Burra Charter” adopted by ICOMOS, 1978 (Australia) which was based on the principles of the Venice Charter, 1964 adopted by ICOMOS, 1965 where the concept of ‘place’ is used to replace ‘monument’ and ‘site’ with a view to keep the relationship of the traditional setting without radical modifications and also to view the building/groups of buildings or other works with pertinent contents and surroundings.

Nevertheless the aim of these International Charters and recommendations is to provide a yard stick for the definition of the quality standards required for conservation treatment of the historical structures.
2.2.2 Conservation of Monuments - National

Although the conservation of monuments in India, received attention at the end of the 18th century, real interest started only after India’s independence. Broadly speaking, the management of cultural property in India is divided into the following categories (Jeyaraj 2003)

1. Monuments, wall paintings and other immovable cultural property
2. Movable art objects like sculptures, bronze images, wooden objects, textiles, manuscripts, paintings etc.,
3. Archival materials, documents and similar materials.
4. Library materials

Any structure crossing a life span of 100 years is termed as a monument and monuments of national importance are taken care of by the most important and primary institution, the ASI. The ASI, a central Government organization has two main wings for conservation, namely structural conservation, headed by The Director (Conservation) and chemical conservation, headed by The Director (Science). The Archaeological Survey of India (ASI) has 4 Zonal offices North, South, East and West; under each zonal office there are several circle offices which take care of the monuments under their jurisdiction. The conservation Manual written by John Marshall is the first handbook serves as a guide for the conservation of Ancient monuments protected by ASI (John 1923).

Each state has its own State Departments of Archaeology (SDA) division to protect the monuments in that state. The monuments of regional importance come under the jurisdiction of this institution.
The first laboratory of the ASI is located in Dehradun and takes care of the chemical analysis part in the conservation of monuments and antiquities. Now, there are conservation laboratories established in each state of India to cater to the needs of the respective states.

The Department of Culture of the Government of India established a national research institution in the field of conservation with the help of UNESCO in 1976, NRLC – National Research Laboratory for Conservation of Cultural Property at Lucknow. At present NRLC has the finest and the most advanced equipment for analysis and research. Attached to it is an excellent library on conservation, and research work is being done in the areas of stone, terracotta, metal, textile, paper, manuscripts and bio-deterioration. NRLC has set up a Regional Conservation Laboratory at Mysore to serve the needs of conservation in South India.

However, a majority of architectural heritage in India still remains unidentified, unclassified, and unprotected, thereby subject to attrition on account of neglect, vandalism and insensitive development. The Indian National Trust for Art and Cultural Heritage (INTACH), a wholly autonomous Non-Governmental Organisation was set up in 1984 for the conservation of natural and man-made environment. A very significant development in the area of conservation is the establishment of INTACH which has conveners throughout the country to mobilize public participation and opinion for the cause of conservation and preservation of the nation’s cultural property. It has set up a unit for conservation called the “INTACH CONSERVATION CENTRE” at Lucknow, to undertake projects for conservation. It also organizes several workshops and training programmes for professionals who are in the field of conservation and also for the public to create an awareness and to involve them in projects to save the country’s heritage. INTACH has a charter called The Charter for the Conservation of
Unprotected Architectural Heritage in India which provides standards for the conservation of the architectural heritage of unprotected monuments (INTACH Charter, www.intach.htm).

Though machinery has been set in place for the conservation of architectural and cultural heritage in India, it is insufficient to manage the numerous monuments and heritage sites in the country.

2.3 CONSERVATION OF STONE MONUMENTS

The following section deals with the review of literature and research done on the conservation of stone as a monumental material at the national and international levels. Mechanisms of stone decay need to be understood before working on the conservation of stone as a monumental material.

2.3.1 Mechanisms of Stone Decay

“Before we can take any action to prevent or to remedy the deterioration of stone, we must understand what is causing it. Sometimes, the cause is obvious; sometimes there may be several different causes acting at once” (Price 1996).

The causes for the deterioration of building stone (Price 1996) in general, are summarized as follows:

i) Dampness: Water is an essential factor in the generation of internal stresses. Water exerts mechanical action during driving rain, storm and freezing. It penetrates a porous stone by means of capillary absorption. Water laden with salts is
transported in stone through capillaries. The rate of leaching is greatest for stones with high porosity. On a moist stone surface the rate of deposition of pollutants is high compared to that on a dry surface. Water in various forms is involved in various types of stone deterioration.

ii) Salt attack: Soluble salts can be originally present in stone before its incorporation into the building or can be derived from external sources such as soil, atmosphere, pointing materials or wrong interventions during cleaning and maintenance. In the presence of moisture and thermal ingredients, these salts migrate towards warmer parts. The dissolved salts in the moisture turn into crystals after evaporation called crystallization. Soluble salts may crystallize on the surface of the stone forming unsightly deposits known as efflorescence. The salt crystals form and grow in the pores and exert forces on the surrounding stone known as crypto-florescence or sub-florescence. The most common salts occurring in efflorescences are sulphates, chlorides, nitrates and carbonates.

iii) Decay due to thermal variations: Stresses are developed in building stones due to thermal changes and diurnal variations. Most of the rocks are poly-minerallic in nature; each mineral expands in different rates, thus setting up minor stresses and strains which tend to pull apart the minerals and disrupt the rocks. Sudden cooling of the outer surface during rain causes a strain between the outer and inner portions of the rock elements in buildings, which results in disintegration.
iv) Decay due to atmospheric pollution: As various atmospheric pollutants are present simultaneously, it is difficult to point out the effect of one pollutant and no pollutant acts in isolation. Hence the decay due to the pollutants is complex. Carbon monoxide, ammonia, hydrogen chloride, hydrogen sulphide, ozone, particulate matter and sulphur oxides are the common harmful atmospheric pollutants.

v) Bio-degradation of stone: Algae, moss and lichens are commonly found on damp stone surfaces. The growth becomes rapid immediately after rainfall, showing up bright green in colour and becomes dry imparting a dark appearance. Acids generated from moss and lichens leads to damage of stone. Growth of small plants and vegetation causes physical stresses due to propagation of roots; further, the roots penetrate the joints and lead to cracks. Dampness is retained on the stone due to the presence of vegetation thus inducing continuous damage.

vi) Decay due to quarrying and dressing: The micro cracks formed during the quarrying of stones lead to the entry of salt and acid solutions.

2.3.2 Conservation of Stone Monuments – International

The working group “Natural stones and weathering” at the Geological Institute of the Aachen University of Technology, Germany has a long-term experience in material and damage investigation of natural stones. The methodology developed by this group ‘monument mapping’ helps in quantifying the decay of stones. By means of monument mapping, the type, extent and distribution of the stones used and its damages are precisely
documented. An investigative method has been developed enabling us to record in detail weathering damages according to objective and reproducible criteria. The mapping results represent the basis for an evaluation of the damage situation and they are fundamental for damage analysis. By means of detailed mapping, the state of the monument can be observed on a long term basis and the resulting modifications can be registered. In addition to monument mapping, measuring procedures are applied for evaluation of damages (Stone, www.stone.rwth-aachen.de).

This non-destructive method guarantees precise classification, registration, documentation and evaluation of stone types and degradation phenomena of natural stone monuments (Fitzner et al 1993, 1997; Fitzner and Heinrichs 1994, 1998). The monument mapping method is part of an in situ investigation of monuments and is focused on stone deterioration at the mesoscale. The method can be applied to all stone types and to all stone monuments. It provides detailed information on the entire stone surface of monuments (Appendix 1).

The systematic documentation of suitable monument preservation is subdivided into three important interdependent parts - anamnesis, diagnosis and therapy. The anamnesis is to acquire, compile and evaluate all available information, data and documents concerning the monuments and their history. A comprehensive anamnesis has to consider all important aspects like monument identification, location, art-historical portrayal, case history and environment. The information provided by the anamnesis represents the first important contribution to the understanding of the monument situation and the state of damage.

The anamnesis is consequently followed by diagnosis. The overall aim of the diagnosis is analysis, quantification, interpretation and rating of
stone deterioration and stone damage considering weathering factors, weathering processes and weathering characteristics as well as stone types, monument characteristics and time factor. The diagnosis uses the information provided by the anamnesis and it represents the basis for the decision and implementation of appropriate preservation measures. Subsequent to preservation measures, repeated diagnostical activities facilitate control/certification of the preservation measures and, further more, prevention of new damages, long term monitoring and maintenance of monuments.

This systematic approach has been applied very successfully on historical stone monuments in France, Spain, Italy, Malta, Turkey, Greece, Egypt, Jordan, Brazil and Chile (Fitzner et al 1993a; Fitzner and Heinrichs 1994, 1998a, 1998b).

Fitzner and Heinrichs (2004) had developed a detailed classification of weathering forms as the basis for precise, objective and reproducible registration and documentation. Components of the classification scheme are four levels of differentiation, definitions of weathering forms, symbols for registration and data processing, parameters for intensity, classification of the weathering forms and photo atlas. The consequent use of weathering forms, damage categories and damage indices allows manifold scientific and practical evaluation. Based on defined schemes, all weathering forms are related to damage categories. The damage categories have been established in order to rate the different types of damage. Damage indices have been introduced for conclusive quantification and rating of damage. Damage indices are calculated based on quantitative evaluation of damage categories (Fitzner and Heinrichs 2002; Heinrichs and Fitzner 2000).

Fitzner et al (2003) conducted pilot studies on the petrological properties of sandstone and their state of weathering damage for the Karnak
Temple and the Luxor temple, the Gebel el-Silsila region, Egypt. A survey of historical quarries was carried out to obtain replacement material from different locations and to study the characteristics of sandstone. An analysis of the characteristics of sandstones revealed that considerable variations are there with respect to their petro-physical properties. The weathering forms present on the sandstone and quantification of weathering forms were done by monument mapping. Based on the intensities of weathering forms, damage categories and damage indices were established for quantification and rating of weathering damage. The investigation areas show considerable proportions of moderate, severe or even very severe damage. It concluded that the degree of damage on the investigated areas did not correlate with their age and it appeared to be more dependant on the exposure characteristics of the investigation areas and the local environmental conditions, especially as related to salt weathering processes.

Weathering research group – Queen’s University Belfast - The Weathering Research Group (WRG) has an extensive track record of research into the weathering mechanisms affecting stone in natural and urban environments. The WRG is a complementary team of researchers who publish and network together nationally and internationally and have built upon quality research to establish themselves as the largest UK centre for pure and applied research into stone properties, natural rock weathering and urban stone decay. In addition to producing good science, a major strategy of the WRG is the development of an interdisciplinary approach to complex weathering issues. International leadership in this area is reflected in conference organisation and collaborative research links. In addition to their track record of research into stone decay processes, recent studies by the group have also begun to encompass the social dimension of cultural heritage conservation.
A photo atlas had been developed for decay features occurring in stone and these were broadly classified into four categories, namely, Alteration/Deposition, Human Damage, Mechanical break-down and Solution (Queen’s University, Belfast, www.weathering tutorials). This is similar to Fitzner’s classification of weathering forms (Fitzner 2004).

Turkington et al (2003) conducted experiments of siliceous sandstone and calcareous sandstone. The study was conducted on natural exposure and sheltered environment, and registered surface change and decay of sandstone in a polluted urban atmosphere over a six-year period. The results suggest that sandstone decay in a polluted urban atmosphere may be rapid and cause marked surface change within a short period, relative to the life expectancy of stone buildings and monuments.

Historic Scotland is an agency within the Scottish Executive Education Department and is directly responsible to Scottish Ministers for safeguarding the nation's historic environment, and promoting its understanding and enjoyment. Historic Scotland funded several research projects in order to conduct an extensive research on Scottish architectural heritage. The research projects done on the sandstone of Scotland provide an important work of reference for practitioners and academics who are interested in conserving stone buildings and monuments (Historic Scotland, www.mcrg/publications). One of the research projects was ‘Effects of stone cleaning methods on Scottish sandstones’. This research examined the effects of physical and chemical stone cleaning methods on building sandstones and determined which tests should be performed on the sandstone prior to cleaning, to choose a stone cleaning method which will not result in excessive damage to the stone (Webster et al 1992).
Another research project was ‘Sandstone consolidants and water repellants’. The aim of this programme was to research the effects of modern consolidants and water repellents on Scottish sandstones and their success in reducing the rate of stone decay and of consolidating existing decayed stone surface (Young et al 1999).

Tiano et al (1999) conducted weathering studies on monumental stones and studied the physical, chemical and biogenic factors contributing to the deterioration of stone. They concluded that weathering by environment induces progressive material dissolution by loss of material cohesion. Prikryl et al (2003) conducted accelerated weathering studies to determine weathering on Marlstones used in the historic buildings of Prague.

SWAPNET (Stone Weathering and Atmospheric Pollution Network) - This network is an informal association of academics, conservators and others interested in the processes and forms of stone weathering and the application of scientific methods to the conservation and preservation of natural building materials. SWAPNET was formed as a discussion group in the late 1980s and has since developed links between academics in geomorphology, geology and microbiology. The network has no formal organizing committee or structure. There are no formal membership requirements or qualifications. Each year a member offers to organize a meeting to discuss stone weathering and conservation. Initially such meetings were fairly small affairs, but from the Belfast meeting of 1995 onwards, larger meetings with full paper sessions as well as informal discussions have been organized.
2.3.3 Conservation of Stone Monuments – National

2.3.3.1 Stone monuments in India

“The rich Architecture of India is a reflection of the geological diversity of the nation. Creative ideas for utilizing locally available building stone brought new styles in architectural design and structural construction” (Kumar 2001). The geology of different regions provided the very material for construction and determined the nature of the different architectural styles, which is evident in different monuments, constructed out of different materials styles throughout India.

Any stone can be placed geologically into one of the three groups and have been derived from igneous rocks, sedimentary rocks and metamorphic rocks. The following geological map of India (Figure 2.1) shows the distribution of different kinds of rocks.

Figure 2.1 Geological map of India
2.3.3.1 Igneous stones

The beginning of the architectural developments in igneous stone started with rock-hewn structures. Among the earliest surviving examples are Ajanta (Gupta Dynasty), the Mahabalipuam cave temples (Pallava Dynasty), Ellora and Elephanta (Chalukya and Rashtrakuta Dynasties).

2.3.3.1.2 Sedimentary stones

Sandstone was the most popular building stone and the first evidence of the use of sandstone as a sculptural and architectural medium was found during the Mauryan Dynasty. Ashoka’s pillars are famous examples of artistic work in sandstone. It is among the hilly tracts of Madhya Pradesh, that the majority of the earliest surviving sandstone architectural monuments are found. Sandstone wonders from the post-Gupta period survive throughout Northern India and are scattered in the states of Rajasthan, Gujarat, Maharashtra, the whole of Madhya Pradesh and Bihar. A remarkable example is the Sun temple, Modhera, built in the 11th century. Sandstone continued to remain the preferred medium of the Muslims, the finest examples being the Qutub Minar, Delhi and Fatehpur Sikri.

Limestone from the Kurnool formation was the most popular building stone in Andhra Pradesh; the famous example is the Stupa of Amaravati and the limestone sculptures.

2.3.3.1.3 Metamorphic stones

Lime stones, dolmites and marbles of varying compositions were used in northern and western India in Hindu, and Jain temples and in Mughal monuments. The famous example is the Dilwara temple, Mount Abu,
constructed out of white marble and the exceptional world wonder the Taj Mahal at Agra. The Gandhara sculptures of the Kashmir region are made out of blue-gray Mica Schist.

The ferruginous garnetiferous schist known as Khondolite was used extensively in the monuments of Orissa. The famous example is The Sun Temple, Konarak, located in one of the world heritage sites.

A series of Schist belts is the major feature of Karnataka and it extends east into the state of Andhra Pradesh. The greenish blue chloritic schist is used in several monuments in Belur, Halebid and Somnathpur in the state of Karnataka.

The prominent hill ranges in Tamilnadu are made up of granulites. The famous examples of architecture built with gneisses are the Shore temple at Mahabalipuram built by the Pallava Dynasty, the Brahadehswara Temple at Tanjaur built with granulites by the Chola Dynasty; both are listed as world heritage monuments. Tamilnadu being a granitic region, there are only a few monuments made of sandstone primarily built during 674 A.D – 800 A.D and the study focuses on these monuments which have National and Regional importance.

The different varieties of stones used in Indian monuments include granite, schists, gneisses, sandstone, quartzite, limestone, dolomite, marble, basalt and laterite.

Table 2.1 lists the different types of stone used in Indian monuments (Jain 2003).
## Table 2.1 Types of stone used in Indian monuments

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Types of stone used</th>
<th>Names of the Monuments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sandstone</td>
<td>Red Fort, Agra; Jami masjid, Delhi; Qutub Minar, Delhi; Fatehpur Sikri; Sun temple, Modhera; Rano-ki-vav, Patan; Sikandara, Agra; Mathura Sculptures; Lingaraja temple, Puri; Udayagiri caves; Khandagari caves; Bagh caves; Portugese ports, Diu; Asoka Pillars, Sanchi; Rajasthan Havelis; Bibi ka Makbara, Aurangabad; Victory Tower, Chittorgarh; Sibsagar temple, Assam.</td>
</tr>
<tr>
<td>2</td>
<td>Marble</td>
<td>Taj Mahal, Agra; Moti Masjid, Agra; Itmad – Ud Daulah, Agra; Jaswand Thada, Jodhpur; Dilwara temples, Mount Abu; Victoria Memorial, Kolkatta.</td>
</tr>
<tr>
<td>3</td>
<td>Granite</td>
<td>Brahadehswara Temple, Tanjavur; Thousand pillared temple, Hanamkonda; Golkonda Fort, Hyderabad; Chausath Yogini Temple, Khajuraho; Vidan Sauda, Bangalore.</td>
</tr>
<tr>
<td>4</td>
<td>Chorkonite</td>
<td>Shore temple, Mahabalipuram; Vivekananda Memorial, Kanyakumari.</td>
</tr>
<tr>
<td>5</td>
<td>Basalt</td>
<td>Kailash temple, Ellora; Ajant caves, Elephanta caves Mumbai; Bhaja caves; Carla caves</td>
</tr>
<tr>
<td>6</td>
<td>Khondilite</td>
<td>Sun temple, Konark; Puri Temples</td>
</tr>
<tr>
<td>7</td>
<td>Laterite</td>
<td>Many churches in Goa; Monuments in Kerala</td>
</tr>
<tr>
<td>8</td>
<td>Quartzite</td>
<td>Almora temples; Qutub Minar, Delhi; Chamba monuments, Himachal Pradesh</td>
</tr>
<tr>
<td>9</td>
<td>Lime stone</td>
<td>Dwaraka temple, Monuments at Avantipur, Kashmir</td>
</tr>
<tr>
<td>10</td>
<td>Limy-Shale</td>
<td>Pushpagiri temples, Cuddapah</td>
</tr>
<tr>
<td>11</td>
<td>Soapstone</td>
<td>Hoysala temples, Halebid; Chenna Kesava temple, Belur</td>
</tr>
</tbody>
</table>

Source: Jain K.K. (2003), Special volume on Conservation of stone with special reference to lime stone.
2.3.3.2 Weathering of stone monuments in India

Depending upon the climatic condition of the region where these stones are present, environmental agencies play a role in their deterioration. However, the extent of decay also depends on whether the stone is present inside or outside. Usually, the rate of decay is more outside than inside because of the action of different deteriorating agencies.

The factors responsible for the deterioration of stone in Indian monuments can be broadly categorized as chemical weathering, physical weathering and biological weathering; they never affect the monuments in isolation. The common problems faced by Indian stone monuments (Agarwal 2003) are as follows:

1. Surface erosion – As a building is in the open and is exposed to the sun, the rain and the wind, its exterior surface gets eroded and quite often pitting is formed on it.

2. Effect of sea breeze – The monuments located on the coast face this problem. The classic examples are those of the Shore temple at Mahabalipuram, Tamilnadu and the Sun temple, Konark, Orissa. Apart from erosion by the sea breeze, the stone gets saturated with salts on account of salt contained in the air.

3. Exfoliation of stone layers – The layers of stone, particularly of the sedimentary rock-like sandstone separate and split.

4. Formation of cracks – Cracks of various dimensions develop in stones of all types. In the marble of the Taj Mahal, there are cracks all over the surface.
5. Control of micro-organisms – India, with a tropical climate, having rainfall and plenty of moisture, the growth and development of different types of micro-organisms on stone is very natural. These micro-organisms grow very quickly and cover the surface of the monuments.

6. In India, there are many statues, which are quite high. Examples are the statue of Bahubali at Sravana Belegola, the Statue of Bhagvan Adinath at Bawan gaja, and the Statues of the Jain Thirthankara in Gopanchal in Gwalior. There are also a large number of monolithic decorative or inscribed pillars; for example, the Jain Manustambh at Kahun in Deoria district, in Utter Pradesh. There are a large number of Ashoka pillars also. These statues and pillars suffer from almost the same type of damage and deterioration as found in the monuments. To reach the top of the statue scaffolding has to be erected, which would surround the statue on all the sides.

Although several research scholars have worked on weathering of stone monuments in India, the problems faced by conservation authorities are multifold and therefore research needs to be intensified.

2.3.3.3 Research works done on stone conservation in India

“The history of conservation of stone materials in India, about 100 years old, is the history of the preservation of its monuments, although there are some instances of repair of monuments earlier to this also. For example, that of the Taj Mahal in 1808, Fatehpur Sikhri in 1815, Qutub Minar in 1826 and Ahmednagar Fort in 1867. However, regular conservation could

“Although India possesses a very vast cultural heritage in stone and the problems posed by these are also of a varied nature, stone conservation research as a discipline has not received the attention that it deserves. In order to safeguard our heritage in stone, it is imperative that a systematic approach to the problem is adopted. Though some of the studies are preliminary in nature, the results are promising” (Jain 2003).

Lal (1985) studied the weathering of some stone monuments in basalt, tuff, khondalite and granite by determining the leaching index and suggested that chemical weathering takes place due to kaolinisation of feldspars, limonitisation of garnets and desilicification of silicates as well as alkalis followed by accumulation of sesqui-oxides.

The conservation status of the Taj Mahal, one of the World Heritage monuments in India, has been the subject of several studies. Studies were conducted to examine the deterioration of the Taj Mahal marble because of air pollution and subsequently a number of steps were taken to reduce the pollution around the Taj Mahal (Agarwal 1986; Agarwal et al 1988). The decay of the Taj Mahal due to pollution has not been found true but the study has acted as a catalyst to raise the issue of the deterioration of cultural heritages on account of air pollution.

Agarwal (1986) studied the deterioration of marble used in the Victoria Memorial, Kolkata. He reported that the corrosion of copper iron clamps is responsible for the presence of green and reddish – brown patches over the marble and its consequent decay.
The discoloration of the Taj Mahal marble was studied by Agarwal and co-workers (1987) who observed the presence of calcium oxalate in the crust. Sharma (1993, 1996) studied the discoloration of the Taj Mahal marble and concluded that a patina of oxalic acid over marble is protective in nature and the metasomatic action of ammonium oxalate on marble surfaces could help in stopping further dissolution of eroded surfaces.

Tandon (1989) analyzed weathered and un-weathered stone samples from the Khajuraho temples. He also measured metrological parameters and studied the biological growths found on the stone surface and observed that the acids produced by lichens were the reasons for the biodeterioration of the stones used in these temples.

Jain et al (1989) studied the effects of biogenic acids on marble, sandstone, khondalite and coral stones, and concluded that calcareous stones are more susceptible to damage by biogenic acids and the damage is also directly proportionate to the available surface area.

Over the years, the use of synthetic polymers has increased globally for the conservation of stone. Varieties of these polymers are available in India and have been used for different purposes like consolidation and water repellency. Based on laboratory studies, Singh et al (1995) concluded that organo-silanes gave a better account of themselves as consolidants for khondalite stone among a group of polymers used in the study.

In India, the application of lime wash on stone surfaces as a protective layer is followed as a regular practice. Kamalakar and Sreelatha Rao (1996) suggested that the ritual of applying lime wash on the granite walls of temples resulted in their deterioration through the formation of gypsum leading ultimately to pitting of surface. The gypsum content increases
in the rock and the crystal growth permeates into the depths of the stone due to its porous nature. The susceptibility of increased sulphate is the very factor which causes the widening of pores. The water gets into the stone and causes the transportation of gypsum back to the surface, from where it is washed away. When lime wash is applied afresh, a new chain of reactions commences, causing the widening of an already widened pore; so, it can be concluded that the hydration and dehydration of gypsum with temperature and moisture, causes the decay of the stone surface in the long run. The presence of gypsum in large quantities gives rise to significantly increased surface areas, modifying the pore system of the granite.

Mishra et al (1991) made a study on the micro and macro organisms responsible for stone deterioration and described the various steps involved in the identification of the bio-deteriogens. They generally concluded that in order to combat the threat posed by the bio-deteriogens, it is important to carry out regular surveys for qualitative and quail-quantitative data for each monument at regular intervals and the changes in the eco-system should be recorded which may help in the eradication of biological growth from the monuments.

Agarwal (1991) studied the different materials used in the construction of the Victoria Memorial, Kolkatta. Detailed petrographic and x-ray analyses were carried out on the stone and encrustations. This monument is made of brick and cladded with white marble. The petrographic report confirms that no weathering had taken place on the marble but the encrustation on the marble is only the thin superficial deposition on the surface. The chemical analysis gives the high value of lead in superficial disposition and is considered to be derived from the atmosphere and leads to a slight discolouration of marble.
Sharma et al (1997) reported that the conservation problems faced by three world heritage monuments, viz., the Sun temple, Konark, the Kandariya temple and the Taj Mahal mausoleum were the result of building design and functional environment. They conclude in general that the conservation problems of these monuments arose mainly because of the ingression of water and suggested measures to arrest the ingress of water to solve the problems.

Bhargav et al (1997) carried out petrology, x-ray diffraction and chemical analyses of stone samples from monuments at Bhuvaneswar and compared the results with quarry samples. They observed that the sandstone used in the monuments is fine to medium grained. The sandstone had undergone physical and chemical weathering. It was observed that there was no correlation between the age of the monument and the degree of weathering.

Kasthurba (2006) had done a comprehensive investigation for laterite samples from four different quarries of the Malabar region, Kerala, India. An extensive study on physical, chemical and mechanical properties of laterite was conducted. Weathering studies done by in situ investigation, laboratory tests in simulated conditions, field exposure trials in selected natural environments and sheltered exposures were carried out to understand the weathering mechanisms of laterite blocks. The results of the study reveal that properties of laterite are dependent on the location of the quarries and the depth within the quarry. The strength and durability of laterite depends on the relative proportions of iron and clay in the laterite and on the distribution of the iron rich components within the structure of laterite. The primary cause of damage in real life situations is the occurrence of dampness and any treatment that prevents the ingress of moisture into laterite helps in prolonging the life of laterite monuments.
2.4 BOOKS REVIEW

Though there are certain books which have given an over-view of the conservation of monuments, like Fielden M. Bernard (1982); Weaver and Matero (1993); Brereton Christopher (1995), an attempt is made to review books with particular reference to stone conservation.

Price (1996), Stone conservation – An Overview of Current Research, reviews the works on stone conservation, carried out till 1995. It takes a broad, and sometimes critical, look at the present state of stone conservation and of the way in which research is conducted. It looks first at the deterioration of stone and at ways in which deterioration may be prevented or remedied. It then looks at some of the factors that are limiting the effectiveness of research, and concludes with recommendations as to how research might be made more effective. The book is available as pdf file which can be down-loaded from the web site (The Getty Conservation Institute, www.getty educational)

Winkler (1994), Stone in Architecture – Properties, Durability, provides basic information on stone, its properties, durability and all aspects of decay, and the necessary background for the preservationist. The information given, covers the classification of major groups of rocks, the physical properties of stone, and the natural deformation of stone. Further, it deals with the weathering agents which act on stone and elaborates on the physical, chemical and biological weathering of stone. Finally it deals with the preservation of stone and elaborates on the surface sealers and penetrating consolidants used for stone preservation. The book insists that the broad field of general geology is required for a thorough understanding of the process of weathering of a building stone. When it comes to stone decay a fuller
understanding of the properties of stone and the agents involved in the decay of stone is the prerequisite for stone conservation and preservation.

The Proceedings of the International Conference on Stone Cleaning and the nature, soiling and decay mechanisms of stone (1992), edited by Webster is a compilation of research papers dealing with the nature of stones, decay mechanisms of the stones, the different methods used for cleaning of stones, the effectiveness of cleaning over a period of time, the rate of deterioration of stones after cleaning, and micro-biological interactions after cleaning the building stones. Though stone cleaning makes the historic building visually dramatic, considerable risks are there in the final results, in terms of disappointment in meeting the expectations and irreversible damage caused to the stones. Inevitably there is no general solution in cleaning historic buildings; each case will have to be treated on its own merits.

Ashurst and Ashurst (1988), Practical Building Conservation, Volume I, Stone Masonry, is a technical handbook of English Heritage, the practical building conservation series. The contents of the book relate to materials and techniques used in traditional building construction as well as methods of repairing, preserving and maintaining historic buildings made of stone with a minimum loss of the original fabric.

The special volume on Conservation of Stone Objects (2003), edited by Jeyaraj, is a compilation of general and research papers on the conservation and restoration of stone presented at the International Conference conducted by the Govt. Museum, Chennai. The general papers deal with types of stones, geological aspects of stone, and the general methodologies adopted in conserving monuments and museum objects. The research papers are based on case studies of an individual monument and issues related to some unsolved problems in the conservation of stone
monuments in India. The volume highlights the past records of conservation of stone monuments in India and provides direction for future research.

Kumar (2001), Conservation of Building Stones, is based on a survey of historical buildings made of stone in India and the problems faced by them. The deterioration of stone due to different agencies and the remedies suggested to conserve it, are outlined in detail. The book provides details on the different types of stones used for the construction of the monuments in different parts of India with their geological availability.

2.5 SUMMARY AND CONCLUSIONS DRAWN FOR THE PRESENT STUDY FROM THE LITERATURE REVIEW

Jain (2003) suggests the areas of future research in stone conservation in India as follows:

- Characterization of stone - Preparation of data bank of different types of stone used in the monuments using the latest techniques.

- Standardization of the description of decay and measurement of its extent – Standardization of various terms being used for describing different types of decay and quantification of decay to a reasonable degree of accuracy.

- Weathering studies – Identification of the weathering mechanism in order to take appropriate preventive and curative measures.

- Development of suitable cleaning methods and materials – Establishment of the efficacy of the variety of methods and
materials recommended for cleaning by conservators and their cost effectiveness for Indian monuments.

- Search for a suitable consolidant – Identification of suitable consolidants for Indian monuments. Organic and inorganic consolidants tested in developed countries have been claimed to show good results but there is a need to test whether these will behave similarly under altogether different sets of conditions found in tropical countries like India.

- Eradication of biological growth – Standardization of materials and methods used by the conservators for Indian monuments to eradicate biological growth and development of a suitable biocide which is harmless to the surface, but effective in eradicating biological growth suitable to Indian climatic conditions.

India is a country with a rich architectural heritage and the number of monuments and their scale are very large. The management of these monuments by a few Government and Non-Government organizations is a herculean task. Besides, in the state of Tamilnadu there is no legal mechanism to realize conservation of monuments. The research base to execute conservation of monuments in the field is also in the nascent stage and a data base for implementing conservation works is absent in most cases. Although the works on stone conservation can be accessed from journals and conference proceedings there is no organization or research group which has all the records on stone conservation so far done in India.
Therefore, there is a need to develop basic research to provide a database for the conservation of monuments. This study covers one aspect of conservation, namely, providing the database for the preservation and conservation of sandstone monuments in Kanchipuram, Tamilnadu, by trying to understand the stone, its nature, the mechanism of the decay of stone and its preservation and conservation.