Moenjodaro: A World Heritage Site at Risk

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The aim of this paper is to describe the main threats affecting the conservation of Moenjodaro, an archaeological site that prospered from 2350 to 1800 BC in the fertile Indus flood plain of Sindh (Pakistan). Since 1924, when it was first excavated by the Archaeological Survey of British India under John Marshall, the site suffered from unceasing decay due to both environmental and man made factors. In 1972 the Government of Pakistan and UNESCO jointly prepared a master plan for the conservation of the site. However, the major threat is today represented by soluble salts attack (mainly sodium sulphate), rising damp, heavy precipitation in the monsoon season, poor drainage, thermal stress causing walls to lean and decay structurally, visitor behaviour, site mismanagement, and the lack of vegetation. As a result, in 2000 the site was inscribed in the ICOMOS register of heritage at risk. The paper analyses past and present conservation methods, and provides recommendations for future repair and maintenance.

History of the Site

Moenjodaro is located 32 km south of Larkana in Sindh, Pakistan. Because of its proximity to the river Indus and the similarity to other sites, scholars and archaeologists refer to it as the epicenter of the Indus Civilization (Figures 1 and 2). The site flourished in the early Bronze Age (third millennium BC) and the reasons for its abandonment are unknown, but may be due to the regular flooding of the river. The site was built mainly with fired brick (6.3x13.4x27.9 cm) and mud mortar, but mud brick (10x20x40 cm) was also employed for the construction of platforms on which fired brick dwellings were built. It is believed that only 10% of the archaeological remains of Moenjodaro are actually excavated. The Prohibition that is presently in effect will be lifted when conservation of the excavated structures has reached the level of routine maintenance (Briscoe 1997, 5). One of the main events that recently affected Moenjodaro was the construction of the Sukkur Barrage, as explained by Miyagi and Tabata (1992, 8): 'Sukkur Barrage, the largest irrigation dam in the Indus valley, was constructed 120 Km upstream from the site of Moenjodaro in 1933. It enabled the middle basin of the Indus valley to be irrigated for agricultural development, with rice cultivation prevailing in the area. It activated the rise of the ground water table, which deteriorated the remains through salinisation. Also, the full operation of the Sukkur Barrage influenced the flow of the river Indus and its main course shifted further west towards the site, making the flooding of the river one of the main threats for the site conservation.'

The site was inscribed in the World Heritage list in 1980 and since 1964 UNESCO experts and consultants carried out several technical missions with the aim of studying the mechanisms of decay and of proposing appropriate conservation methods. The master plan for the conservation of Moenjodaro was prepared in 1972 and revised in 1997 (Yamada 1997). Its key objectives were river training, ground water control, conservation of structural remains, plantation of salt tolerant vegetation, landscaping, and cultural tourism. In the 1970s the campus was built near the site so as to guest several buildings, amongst which Water and Soil Investigation Laboratory (WASIL); museum; guest house; accommodation for employees; offices; storage rooms for conservation material; offices for the Moenjodaro preservation authority; tourism office; police station; mosque and post office. The WASIL laboratory was set up with the support of UNESCO with the aim of carrying out analysis of conservation material, water, soil, and to collect feedback data on conservation measures.

In 2000 the site was inscribed in the ICOMOS heritage at risk register with the following justification (Jansen 2000, 152): 'In spite of all activities and international support, it seems that the Pakistan Government has difficulties to keep up scientifically with the continuation of the conservation and maintenance plan. The programme suggested by UNESCO, being regular control of the salt-endangered surfaces plus mud brick conservation, does not seem to be executed to the needed standards.' In 2005 the Moenjodaro Conservation and Research Centre (MCRC) was established as a management structure of the site. This was dismantled after one year and at present the organization responsible for the conservation of the site is the Department of Archaeology and Museums (Ministry of Culture, Sports, and Youth Affairs).

Causes of decay

i. Soil Salinity

In Moenjodaro the phenomenon of soluble salts decay takes place in a twofold way:

i. Subsoil water is driven upwards by capillary action through the structures and in so doing it carries soluble salts. Such salts effloresce on the brick surface if the evaporation is slow, and sub-florescence if the evaporation is fast (Figures 3 and 4).

ii. Hygroscopic salts such as sodium sulphate draw water from the air and are put in solution. Phenomena of hydration and dehydration occur because of temperature cycles, and this creates great pressure for both brick and mortar that tend to powder. If the evaporation is slow not only powdering takes place, but also chunks of bricks fall apart.

During the winter, salts tend to crystallize mainly on the northern and western elevations and sometimes on the eastern faces when in shade because the favorable temperature for crystallization is 32 °C. In the summer the phenomenon takes place within the brick fabric with the result that masonry tends to spall (subflorescence). Mud slurry is the best remedy for protecting bricks from decay caused by efflorescence. Furthermore, mud plaster is effective against subflorescence as it can minimize heating of the structures to some extent. The data provided in Table 1 shows that the most common salts are sodium, potassium, calcium, magnesium, carbonate, bi-carbonate, nitrate, nitrite, chloride and sulphate, with sodium sulphate and sodium chloride found in abundance. The analysis further shows that the amount of salts decreases with the increase in depth, and this is suggested by the fact that their concentration is higher at the surface due to evaporation.

Table 1: Analysis of soil samples, bore hole 1 (located near MD 15).

Depth (cm)	SO_4 (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	Ca (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	Mg (mg/l)
0	370	6.1	17.6	11.5	2.2	59.8	19.9
20	280	0.8	16.3	12.5	2.5	38.2	16.0
50	540	0.2	13.6	8.3	2.3	36.3	12.5
100	410	0.5	10.3	0.9	3.4	28.8	1.2
150	400	0.1	11.0	0.7	3.5	20.5	1.3
200	140	0.4	7.5	0.7	3.4	9.4	1.2
250	70	0.6	11.9	0.9	3.7	7.8	0.5
300	140	0.1	7.0	0.7	3.0	8.6	0.8
350	220	0.7	15.0	0.8	6.8	7.4	0.8
400	190	0.4	11.9	0.9	5.3	6.4	4.2
450	530	0.6	9.7	0.9	5.2	9.0	4.9

ii. Rising Damp

The decay caused by rising damp is directly connected to the soluble salts content of both sub soil and water. Irrigation of farmland around the site contributes to the rising in water table, thus affecting the structures. Other factors that affect rising damp include the difference between excavation levels, one-sided excavated structures, and the higher level of the river Indus bed. Ground level at Moenjodaro is 47 meters AMSL whereas river Indus flood level is 50 meters AMSL. Furthermore, the Dadu canal flows at 47 meters AMSL, almost the same level as the site. It should also be mentioned that the sub soil water fluctuates between 41 and 45 metres (AMSL) throughout the year, meaning that the sub soil water level remains almost constant two metres below the surface. Miyagi and Tabata (1992, 11) explain that: 'It is reported that the ground water level in the area was 7.6m below the surface in 1922. It rose to 4.9m in April 1949, and 1.5m in May (rainy season) and 3.7m in October (dry season) of 1964. The primary cause of such change was agricultural irrigation water as supplied by the Sukkur barrage through Dadu canal.' In 1985, in order to lower the water table, the tubewells were installed and a disposal channel was constructed (Figure 2). The tubewells were positioned along the concentric collector drain so as to cause as little harm as possible to the structures, and drilling was done to an average depth of 75.5m below the surface. The water table was lowered to 5.8 m below the surface in the rainy season and to 8.5 m in the dry season (Miyagi and Tabata 1992, 11). At present the tubewells are not working and that overall this project did not prove to be successful against rising damp.

iii. Monsoon Precipitation and Poor Drainage

Monsoon rain is one of the main causes of masonry decay. Fired brick structures tend to be eroded and settle when precipitation is combined with poor drainage (Figure 5). Precipitation concerns the structures at two levels. The erosion of mud mortar, mud brick capping, and fired brick masonry is deeper in the top portion. The lower portion is affected by ponding due to water mismanagement, contributing towards the rising of dampness. Rainwater mostly affects the site from the north and it should also be mentioned that splashing plays a role in the decay of mud mortar. Due to the topography of Moenjodaro's excavations it is quite complicated to drain out water from the site. However, the effort made by MCRC in 2005 proved to be effective and drainage was improved in several areas. Proper topographic survey is essential for the recovery of drainage system, and this is still to be carried out in Moenjodaro. Water needs to be drained slowly as fast drainage causes gullies and holes. In this sense the employment of barriers of sun-dried bricks proved to be effective for the slowing down of rainwater flow.

iv. Structural Decay Caused by Thermal Stress

Temperatures of more than 60 degrees centigrade were recorded on fired brick walls exposed to the sun, and experimental analysis shows that this value significantly drops at a depth of 3 mm from surface (Briscoe 1997, 17). Diurnal fluctuation of temperature is 20 ^{0}C, whilst seasonal fluctuation can be between 4 ^{0}C and 46 ^{0}C. Direct inspection reveals that the lean of walls derive from thermal movements as the majority of structures that are not connected and are therefore free to move individually tilt towards the colder side (north and west). Out-of-plumb walls are a severe problem in Moenjodaro especially in the monsoon season and when proper drainage is not ensured. Furthermore, it was suggested that microfractures may be another result of thermal stress and that these may provide further pore-like structures for salts to crystallize (Briscoe 1997: 17).

v. Man Made Damage

Man made damage is represented by inappropriate past conservation measures and by site mismanagement. Numerous disrepairs were carried out on several structures in the recent past and a full description of the extent of the damage is provided by Fodde (2007a). Inadequate conservation measures were carried out in the past before MCRC due to lack of scientific control. This includes the insertion of damp proof courses made of precast concrete slabs coated with bitumen to block capillarity rise of water, a practice that was carried out until 2001. This is due to the conventional and simplistic idea that 'strong' materials should be used. The resulting consequence was that many structures were heavily damaged.

vi. Lack of Vegetation

As compared to other conservation tasks mentioned in the Master Plan, plantation was given a low priority because it was not considered urgent and is still neglected. Between 1994 and 1997 the Forest and Wildlife Department (Government of Sindh) undertook a study of flora of Moenjodaro and a new survey of the native species was completed in 2005 as part of the MCRC management (Table 2). It is clear that indigenous plants use salts in the shape of ions in the photosynthesis process, they are transported to the stems of the leaves, and that native vegetation has the ability of tolerating salts. This explains that the growth of plants is also affected by the presence of salts and hence their analysis is necessary at different depths. In this context it is important to know the water profile (water table) and the soil profile (grain size distribution and percentage of salts). It is therefore suggested here that as a future task soil samples are taken at the following depths: surface, 20 cm, 50 cm, 100 cm, 150 cm, 200 cm, and then with an interval of 50 cm down to a depth of 4.50 m (overall 11 samples for every hole). Previous research has shown that salts concentration is higher in the first meter from the surface and this was demonstrated after taking temperature readings and showing that after 1m the temperature is constant.

The botanical survey of 2005 was undertaken with the quadrate sample method. The 48 surveyed areas measured 100x100 m each and locations were selected at random. Then the results were averaged out to the whole area under examination. An important reason for carrying out the future plantation is provided by Miyagi and Tabata (1992, 15) who explain that: 'The windbreak of green belts would be developed considering several factors such as wind direction, density of planting as well as composition of plant species. The species adaptable to this environmental condition are Tamarix, Prosopis, Acacia, Populus, and Eucalyptus. It is recommended that shrubs of Salvadora, Agave, Capparis, and Haloxylon and other grass species tolerant to the salinity are planted to make the wind break effective enough'.

Table 2: Result of the flora survey as carried out in 2005.

Botanical and Sindhi name	**Description**	**Percent**
Acacia nilotica (Babul)	Tree	5.9
Albizia lebbek (Siris)	Tree	0.5
Alhagi camelorum (Kandero)	Undershrub	7.6
Azadirachta Indica (Neem)	Tree	0.5
Capparis aphylla (Kirir)	Low shrub	1.1
Conocarpus (Cono)	Tree	1.6
Desmostic bipinnulata (Drub)	Grass	18.4
Eucalyptus camaldulensis (Eucalyptus)	Tree	5.4
Palm (Khaji)	Tree	1.1
Prosopis cineraria (Kandi)	Large shrub	6.5
Prosopis juliflora (Mesquite)	Large shrub	7.6
Salsola foetida (Lani)	Shrub	5.4
Salvadora oleoides (Khabar)	Shrub	22.2
Tamarix dioica (Lai)	Shrub	16.2

Conservation of Structural Remains

Several conservation treatments are adopted at Moenjodaro. The list supplied here describes the methods that proved to be effective after decades of practice:

i. Construction of fired brick buttresses for the consolidation of leaning walls and for preventing collapse. Brickwork is laid with no mortar so as to make the intervention readable as new.
ii. Mud brick *pushtas* for the consolidation of heavily eroded structures at bottom level. Such low buttresses surround the wall base in a stepped pattern so that to act as a protective cover against coving.
iii. Capping with mud brick as a protection against heavy precipitation and thermal stress.
iv. Mud slurrying as sacrificial coat against salts attack. Structures that are heavily affected by salts crystallization are treated with mud poulticing and mud plastered (Khan 1993).
v. Repointing is carried out not as cosmetic measure, but for consolidating those structures that lack of bonding.
vi. Improvement of drainage and replacement of salt affected soil. The second is necessary to reduce the extent to which ground salts affect the structures through capillary rise.

Two types of soil are employed in the conservation of Moenjodaro: clayey and silty soil. Clayey soil is employed for slurrying, drainage and masonry work. Silty soil is used for wall capping and the creation of shallow ponding. The grain size distribution of such soils and their granulometry curves are provided on Figures 6 and 7.

Concluding Remarks

The aim of this section is to draw some conclusions in the form of final statements and recommendations:

i. A more comprehensive study of the archaeological evolution of building techniques of Moenjodaro is yet to be assembled. There is a strong need for research which could gather and review all of the scattered available information. The creation of a broad corpus of work on building archaeology would undoubtedly provide lessons for future conservation initiatives.
ii. In order to minimize crystallization of soluble salts on fired brick, it is suggested that one structure be shelter coated with mud bricks. This experiment should be carried out with mud bricks set on edge over a 10 cm layer of sand, and the structure be conserved before being treated with the shelter coat. This may include repointing, replacement of decayed brick, construction of buttresses for leaning walls, and improvement of drainage.
iii. Mud poulticing and mud slurrying is essential for overcoming the problem of salts as crystallization occurs on the sacrificial coat rather than on the brick face (Khan 1993). However, it is essential that a monitoring system is developed and carried out.
iv. The agricultural land around Moenjodaro has high salts content and this is increased by the irrigation system: fields are inundated with water for weeks and this makes the water table rise (see Figure 2 for proximity of fields to the site). As a result water tends to migrate towards the structures and salts crystallize on the surface. There is an urgent need to stop the cultivation of paddy crops to overcome the problem.
v. Proper scientific investigation should be carried out to know the reason of the lean of walls. On the basis of such scientific analysis, leaning walls should be provided with proper support and a monitoring system should be put into place.
vi. Similarly to what has been done in other sites, conservation interventions should be carried out after extensive laboratory analysis so as to ensure suitability of repair materials and methods (Fodde 2007b; 2008).

The inscription to the ICOMOS Heritage at Risk register has not produced any effective measure against the continuous decay of the site and the proposals made by UNESCO are not entirely put into practice. Furthermore, it is essential that documentation is carried out before and after conservation and this needs to be seriously improved in Moenjodaro.

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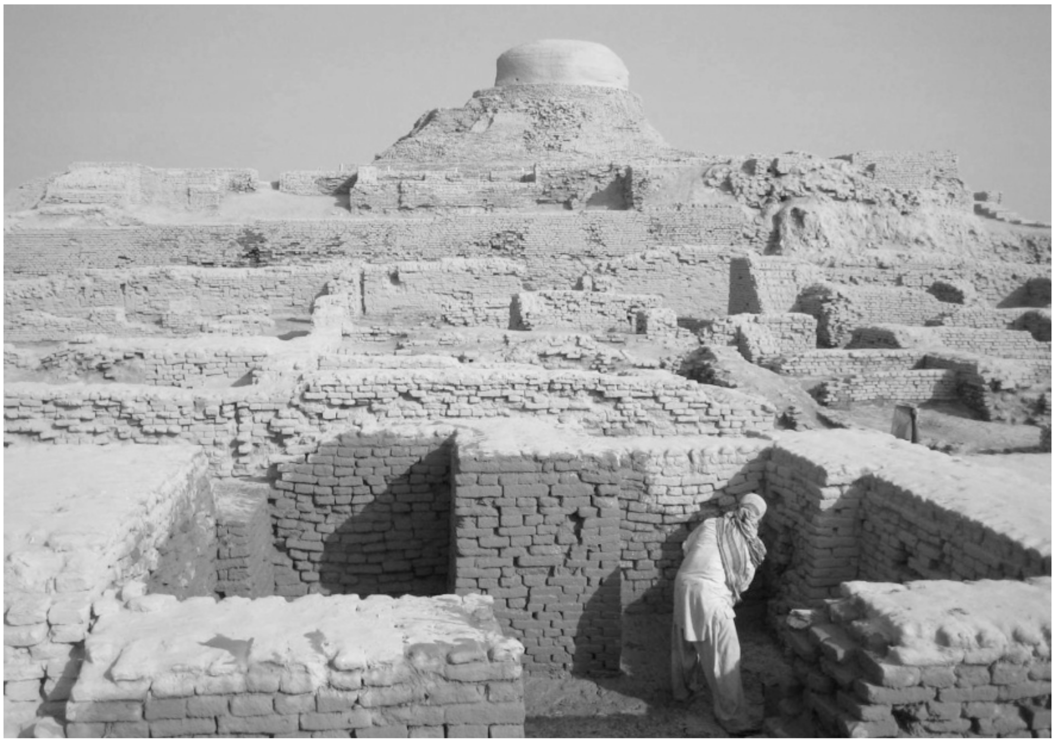

Figure 1: Moenjodaro, View of the SD area with mud brick stupa in the background.

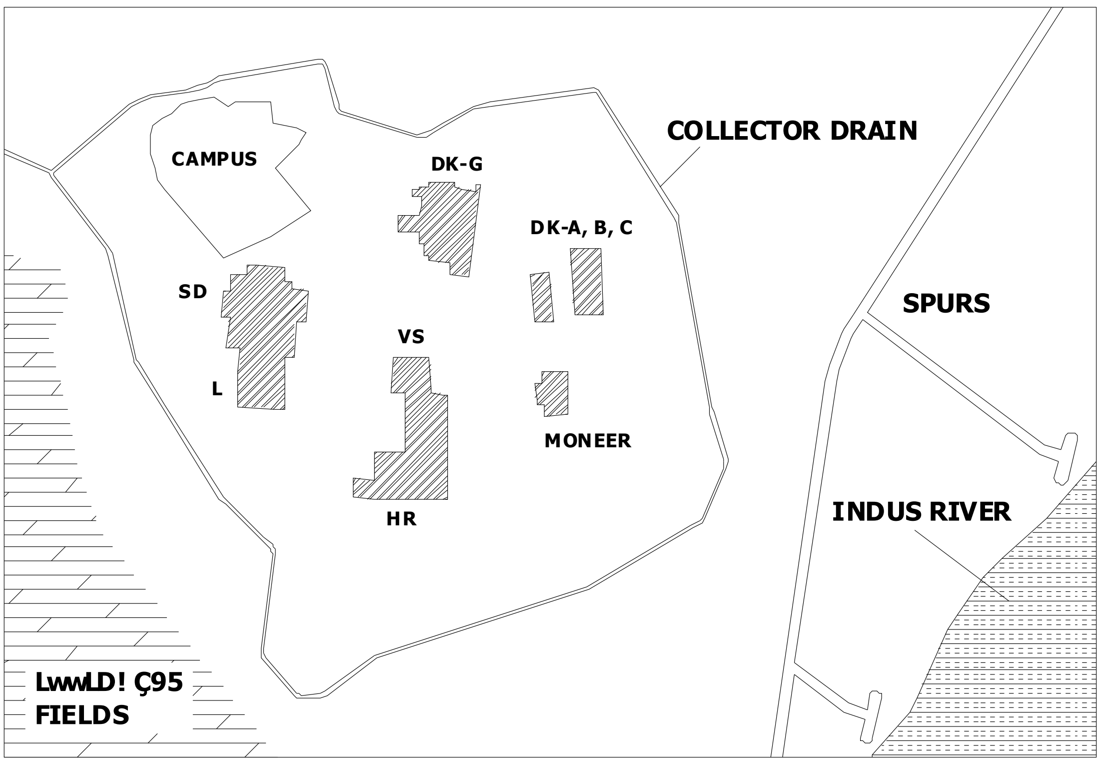

Figure 2: Schematic plan of Moenjodaro with extent of excavated areas.

Figure 3: Moenjodaro, Soluble salts attack at main street, DK-G area.

Figure 4: Moenjodaro, Picture showing DK-G area with salts affected soil.

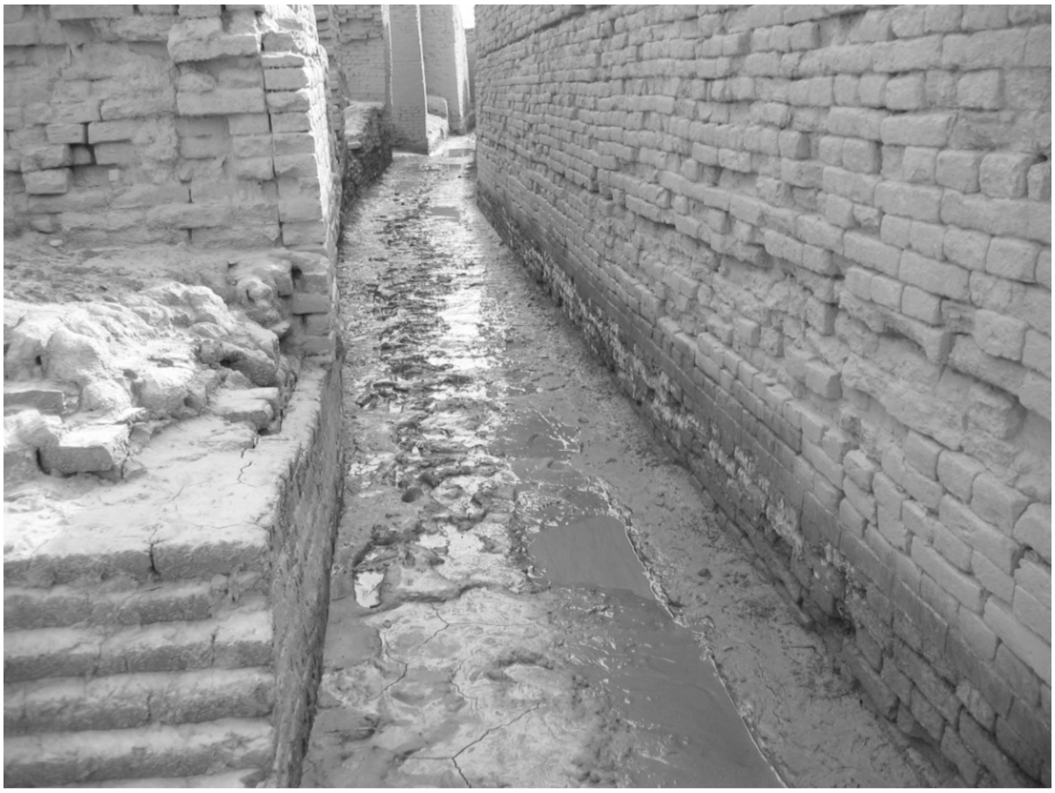

Figure 5: Moenjodaro, Water ponding after monsoon rain, DK-G area.

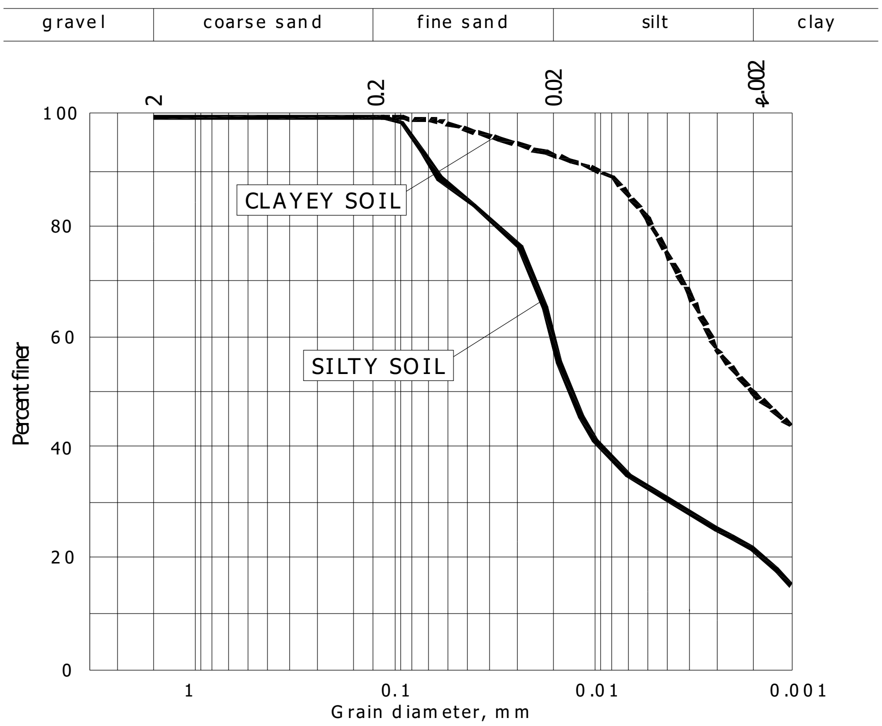

Figure 6: Diagram showing particle size distribution for clayey and silty soil as employed in the conservation of the site.

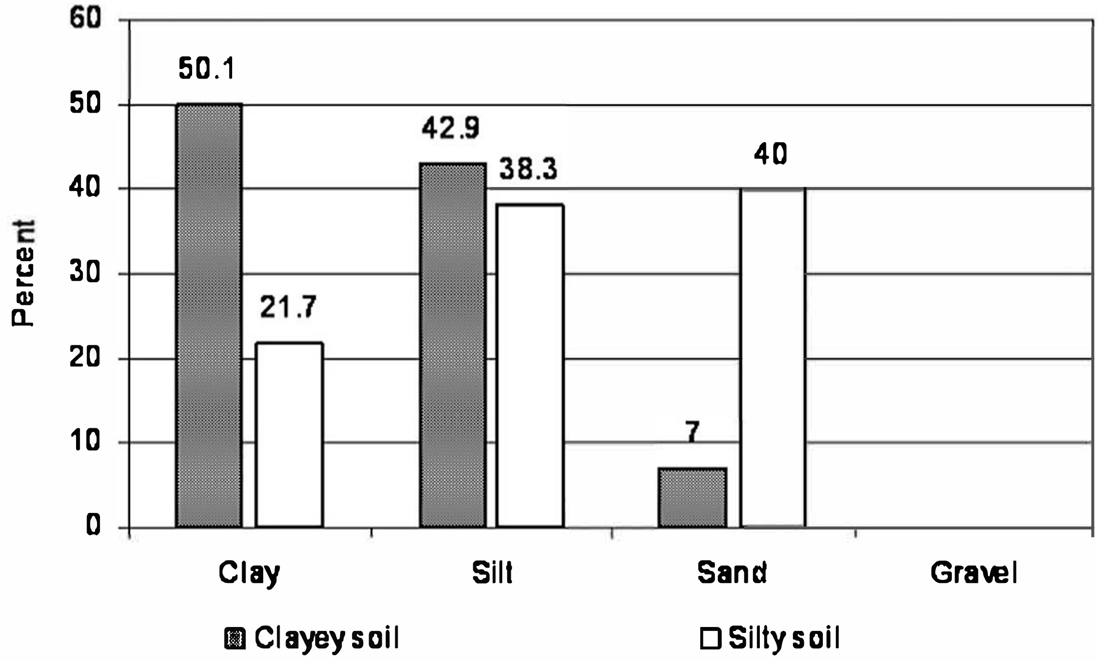

Figure 7: Diagram showing main components for clayey and silty soil (same samples as in Figure 6).