Phase I: Materials Analysis

ROYAL PALACE COMPLEX, DARBAR SQUARE

Patan, Nepal

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prepared for:

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1. INTRODUCTION

This report has been prepared by Integrated Conservation Resources, Inc. (ICR) in response to a request made by the Kathmandu Valley Preservation Trust concerning stone, mortar, efflorescence, and coating sample analyses from various architectural elements at the Royal Palace complex, Darbar Square, Patan, Nepal. Samples and photographs were taken by Konstanze von zur Muehlen during her initial site visit in April 2008 and outlined in her subsequent report dated May 2008. Additional samples were taken by Liz Newman in December 2008. The various materials selected for analyses were extracted from four areas within the Patan Royal Palace complex and adjacent garden (refer to Figure 1 for a plan of the complex and garden):

- Nasal Cok Gate South
- Dui Maju Shrine
- Bhandarkhal Tank and Pavilion
- Tusha Hiti

The objective of this Phase I investigation is characterization of extracted samples by identification of inorganic and organic constituents. Identification is accomplished through the use of petrography, gravimetric analysis, ion identification, and Fourier transform infrared spectrography (FTIR). Table 1 includes a list of extracted samples by location and describes the method of analysis conducted on each sample.

This report presents technical findings from these different methods of analyses. These findings will be used to carry out a unit-by-unit conditions survey at a later date, which will also include extraction of additional samples for more field and laboratory testing in order to have a better understanding of existing historic materials, previous repairs, and decay patterns. This information will then be used to develop a responsible conservation treatment plan.

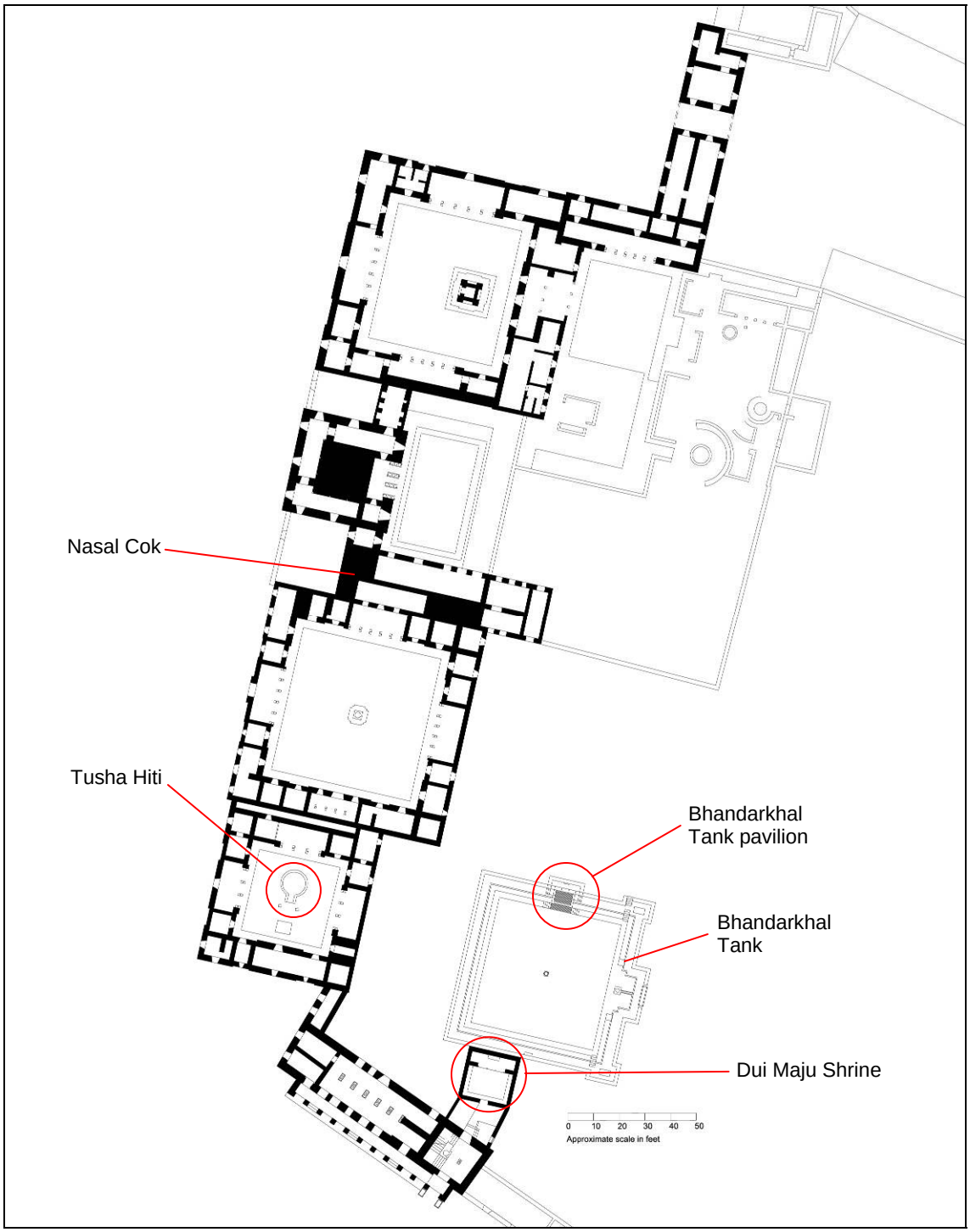


Figure 1: *Site plan of Royal Palace complex and garden.*

TABLE 1

Sample	Sample Type	Description (from May 2008 report)	Test conducted
Nasal Cok Gate South			
S1	Stone	Third decorated field of left door frame, sample taken from deteriorated area (granular disintegration)	Petrography
Dui Maju Shrine			
M1	Mortar/Salt efflorescence	Very soft, heavily salt loaded mortar from joint on top of shrine, very damp	Ion analysis
Bhandarkhal Tank and Pavilion			
A1	Salt efflorescence	Pavilion west corner stone, efflorescence on stone surface, already damaged stone	Ion analysis
A2	Salt efflorescence	Inside Pavilion on mortar	Ion analysis
A3	Salt efflorescence	Inside Pavilion on stone surface, mix of salt efflorescence and crust	Ion analysis
A4	Salt efflorescence	Outside Pavilion east wall, efflorescence on stone surface, under cement repair, already damaged stone (powdering), combination salt iron	Ion analysis
C1	Coating on stone (acrylic layer)	Already damaged area, small figure, piece of stone with crust and layer	FTIR
M2	Mortar	Wall under pavilion from joint, repair from 2007, soft mortar, relatively fine sand	Gravimetric analysis
M3	Mortar	So called suki mortar, traditionally used material, probably from repair after earthquake in 1934, mix of lime, brick stone dust and sand	Gravimetric analysis
M4	Mortar	North wall first level joint, hard, coarse sand	Gravimetric analysis
M5	Mortar	Under pavilion, fat hard mortar, fine sand, prob. 1957, also used for repair of pavilion carvings	Ion analysis
M8	Mortar with coating	From carving at Pavilion, cement repair mortar prob. Same as M5 but with acrylic? layer	FTIR
S2	Stone	Niche under pavilion west side, yellow/grey stone (limestone?), sample taken from scale	FTIR
S3	Stone	West wall, second level, iron crust scale	FTIR
S4	Stone	Top of small image in additional brick wall on top of tank water outlet (grey/black stone prob. monomolythic)	Petrography
Tusha Hiti			
A5	Salt efflorescence	East side upper part, on surface of yellow/grey stone (prob. limestone) mixed with microbiological deposit and crust	Ion analysis
C2	Deposit	Ninth small image (black stone) from east side on top of tank, black deposit prob. Mixed with biofilm, seems to damage the stone (maybe deposit from acid rain?)	FTIR
M6	Mortar	From left corner of center decoration field, repair of carvings, hard, fine sand, fat	Gravimetric analysis
M7	Mortar	Joint mortar, soft, maybe lime mortar	Gravimetric analysis

2. PETROGRAPHIC ANALYSIS

2.1 Methodology

Petrographic analysis allows for observation of grain structure and identification of constituent minerals. Samples selected for analysis include the following, by area:

- Nasal Cok Gate South: one stone sample (S1)
- Bhandarkhal Tank and Pavilion: one stone sample (S4)

These samples were submitted to a petrographer for optical mineralogy investigation. Samples were prepared by vacuum impregnation with clear epoxy and then slicing a thin section approximately 30 microns thick. Thin sections were then mounted on a slide for observation under a stereo binocular microscope in reflected light and a polarizing microscope in transmitted light at magnifications from 40x to 400x. A synopsis is provided below; for the complete report refer to separate document titled Petrographic Analysis for Patan Royal Palace Stone, dated November 27, 2008, submitted by Schnabel Conservation LLC.

2.2 Findings

2.2.1 Nasal Cok Gate South

2.2.1.1 Stone Sample S1

This stone is yellow in color and can be classified as a coarse siltstone or a very fine grained micaeous sandstone (sedimentary). The majority of its composition is quartz with feldspars and muscovite in smaller quantities. The intergranular spaces are believed to be iron hydroxide (limonite) which can act as a cement in sandstones. The porosity is estimated to be 5-6%.

Figure 2: *Location of Sample S1 (left) at Nasal Cok Gate South and detail of sample (right).*

2.2.2 Bhandarkhal Tank and Pavilion

2.2.2.1 Stone Sample S4

This stone is grey-black in color and can be classified as a phyllite (metamorphic). The predominant minerals are quartz and mica with a presence of chlorotoid, chlorite and corundum. The sample also contained a distinct layer at its surface that was composed of grains dissimilar to the underlying stone that were a coating or dirt. For example, calcite was not found in this stone, yet its grain size was not fine enough to suggest a whitewash or pigment. The in-hand specimen also contained bright red particles that appeared to be pigment.

Figure 3: *Location of Sample S4 (left) at the Bhandarkhal Tank and detail of sample (right).*

2.3 Comments

The Himalayas are a known plate boundary, but also contain uplifted older sedimentary deposits from the Cambrian and Eocene ages in the high valley of Kathmandu. These sediments are part of the Tibetan Tethys series which crop out more extensively in the northwestern part of Nepal. It is believed that the remaining rock types are predominantly metamorphic, including phyllites. It is therefore possible to say that the stones identified here are probably from local sources.

Further study on larger samples is required to positively source the stone and to more definitively identify the layer seen on the stone from the Bhandarkhal Tank.

3.0 GRAVIMETRIC ANALYSIS

3.1 Methodology

Wet gravimetric methods provide visual characterization and basic compositional information. Samples selected for analysis via standard wet gravimetric include the following, by area:

- Bhandarkhal Tank and Pavilion: three mortar samples (M2, M3, and M4)
- Tusha Hiti: two mortar samples (M6 and M7)

A freshly broken surface of each extracted mortar sample was viewed under a variable magnification, stereo-binocular microscope with a fiber optic light source (3200 Kelvin, with daylight blue filters). The samples were matched to a color standard of the Munsell Soil Color Chart. (The Munsell System of Color Notation identifies color in terms of three attributes: hue, value, and chroma; color standards are opaque pigmented films on cast-coated paper, mounted on charts for each hue).

Each sample was then separated into its three constituent fractions: acid-solubles, fines (e.g., pigment, cement, or clay residue), and sand. Separation was accomplished via wet-chemical techniques. The acid-soluble fraction was removed by digestion with 3M hydrochloric acid. While the acid soluble component of a mortar generally constitutes the lime portion, certain aggregates or cured cements can also contain acid-soluble elements. Levigation and filtration were then used to separate “fines” from sand. It should be noted that acid digestion may not fully digest all binder, so that a small percentage of the final sand and fines weights may include undigested binder. Additionally, a small portion of the final fines weight may include very fine sand particles.

The colors of fines and sand were matched to the Munsell Soil Color Chart. Predominant colors and shapes of sand grains were noted by microscopic examination. Due to the small sample size, sieve analysis was not conducted, and therefore grain size distribution could not be accurately determined according to ASTM standards. However, through viewing under a loupe, a range of grain sizes for each sample was noted. Refer to Appendix A for mortar analysis worksheets.

3.2 Findings

3.2.1 Bhandarkhal Tank and Pavilion

3.2.1.1 Mortar Sample M2

Sample M2 was extracted from a joint in the north wall of the Bhandarkhal Tank and is said to be part of repair work conducted in 2007 (Figure 4). The sample surface had visible salts and the mortar color overall most closely matched Munsell light gray (5Y 7/1), though the sample had a visible white binder. Gross sample weight before digestion was 0.67 grams.

Sand comprised approximately 40% of the sample by weight. The overall sand color most closely matched Munsell gray (2.5Y 6/1) and was composed of grains that were white, yellow, orange, and black, with some mica fragments. Grains ranged in size from fine (0.25 mm) to very fine (0.125 mm), and were sub-rounded to sub-angular in shape.

Fines comprised approximately 26% of the sample by weight, with an overall color most closely matching Munsell light greenish gray (GLEY1 7/10Y).

There were no lime clumps ("blebs") in the sample; strong gas evolution upon addition of acid to the sample indicated a moderate to high lime content. Approximately 34% of the sample weight was acid soluble.

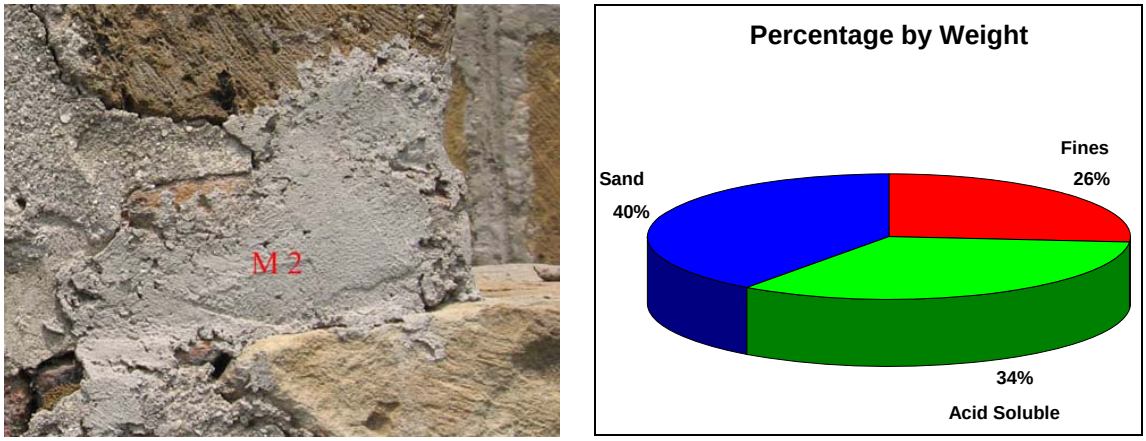


Figure 4: *Location of Sample M2 (left) at north wall of Bhandarkhal Tank, and chemical analysis data (right).*

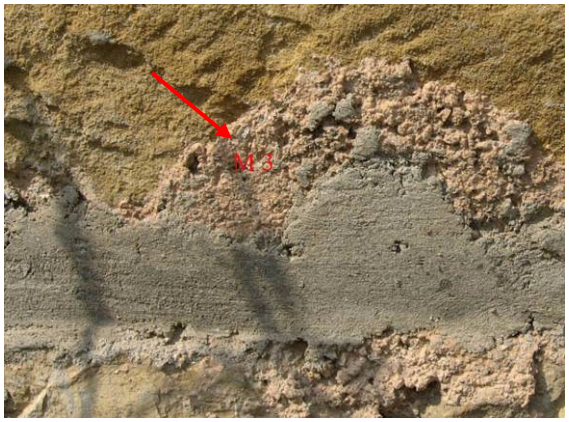
3.2.1.2 Mortar Sample M3

Sample M3 was extracted from the Bhandarkhal Tank and may be a traditional surkhi mortar, a pozzolanic mortar comprised, in part, of brick dust and fragments (Figure 5). The sample may come from repairs conducted following the 1934 earthquake. The mortar contained visible brick and mica fragments and was soft. Viewed in cross section, the overall mortar color most closely matched Munsell warm tan (7.5YR 7/3), with a visible pink binder. The exposed joint surface of the sample was heavily soiled and had aggregate that was clearly exposed, presumably from weathering. The gross sample weight before digestion was 5.57 grams.

Sand comprised approximately 73% of the sample by weight. The overall sand color most closely matched Munsell brown (7.5Y 5/3), and was composed of grains that were white, clear, and black, with many brick fragments and a considerable amount of mica. Grains ranged in size from very coarse (2 mm) to fine (0.25 mm), and were sub-angular in shape.

Fines comprised approximately 11% of the sample by weight, with an overall color most closely matching Munsell reddish yellow (7.5YR 6/6).

There were some lime blebs in the sample; strong gas evolution upon addition of acid to the sample indicated a moderate to high lime content. Approximately 16% of the sample weight was acid soluble.



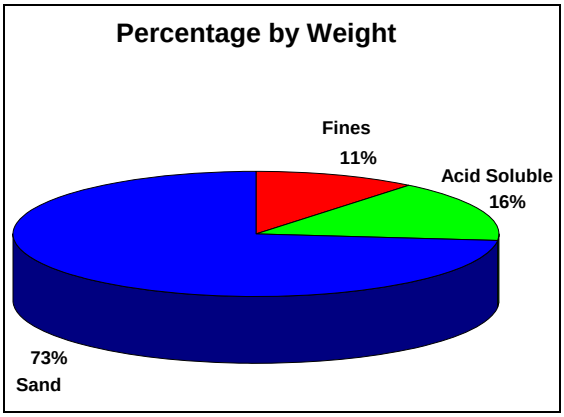


Figure 5: *Location of Sample M3 (left) at Bhandarkhal Tank, and chemical analysis data (right).*

3.2.1.3 Mortar Sample M4

Sample M4 was extracted from a joint in the north wall of the Bhandarkhal Tank (Figure 6). This mortar appears to post-date 1957 as it was found over mortar Sample M5, which is presumed to date to 1957. The mortar was very hard and when viewed in cross section most closely matched Munsell light gray (Munsell Color 2.5Y 7/2) in overall color, with a visible cream binder. The exposed joint surface of the sample had aggregate was clearly exposed, presumably from weathering. Gross sample weight before digestion was 2.42 grams.

Sand comprised approximately 55% of the sample by weight. Overall, the sand most closely matched Munsell light gray (2.5Y 7/1) in color, and was composed of grains that were white, clear, and black, with some brick and mica fragments. Grains ranged in size from coarse (1 mm) to fine (0.25 mm), and were sub-angular in shape.

Fines comprised approximately 15% of the sample by weight, with an overall color most closely matching Munsell white (2.5Y 8/1).

There were no lime blebs in the sample; strong gas evolution upon addition of acid to the sample indicated a moderate to high lime content. Approximately 30% of the sample weight was acid soluble.

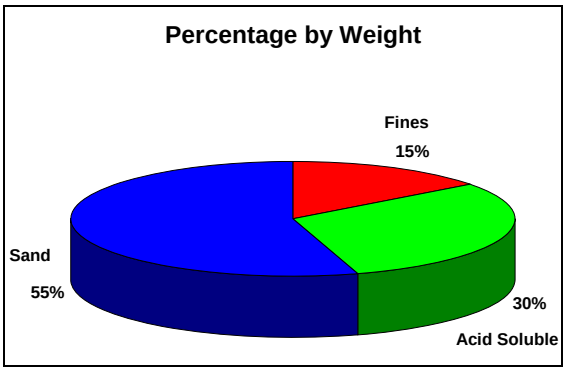


Figure 6: *Location of Sample M4 (left), from north wall of Bhandarkhal Tank and chemical analysis data (right).*

3.2.2 Tusha Hiti

3.2.2.1 Mortar Sample M6

Sample M6 was extracted from repair material on carvings at the Tusha Hiti (Figure 7). The mortar had visible salts and when viewed in cross section the overall color most closely matched Munsell gray (2.5Y 6/1), with a light gray binder. The apparent joint surface of the extracted sample was soiled. Gross sample weight prior to digestion was 0.08 grams. Because this sample was extraordinarily small in size, only rough approximations can be given for the three components (sand, fines, and acid solubles).

Sand comprised roughly 15-20% of the sample by weight. Overall the sand most closely matched Munsell white (5Y 8/1) in color and was composed of grains that were white, clear, and black, with some mica fragments. Grains ranged in size from coarse (1 mm) to very fine (0.125 mm), and were sub-angular to angular in shape.

Fines comprised roughly 20-25% of the sample by weight, with an overall color most closely matching Munsell pale yellow (2.5Y 8/2).

There were no lime blebs in the sample; slight gas evolution upon addition of acid to the sample indicated a low to moderate lime content. Roughly 60-65% of the sample weight was acid soluble.

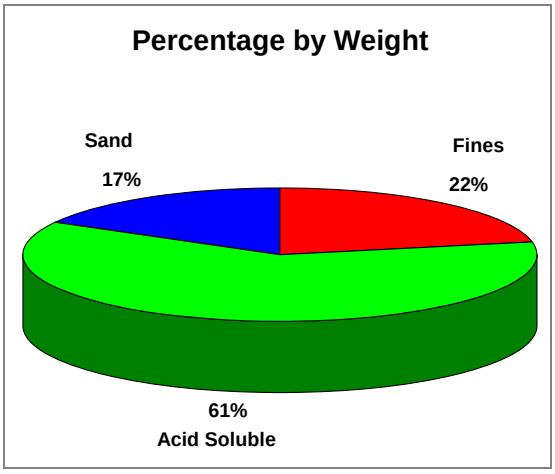


Figure 7: *Location of Sample M6 (left), from repair material on carvings at the Tusha Hiti and chemical analysis data (right).*

3.2.2.2 Mortar Sample M7

Sample M7 was extracted from a joint at the Tusha Hiti (Figure 8). The mortar when viewed in cross section most closely matched Munsell white (5Y 8/1) and had a visible white binder. The exposed joint surface of the extracted sample was heavily soiled. Gross sample weight prior to digestion was 0.54 grams.

Sand comprised approximately 45% of the sample by weight. Overall, the sand most closely matched Munsell light gray (10YR 7/1) in color and was composed of grains that were white,

clear, orange, and black, with some brick and mica fragments. Grains ranged in size from coarse (1 mm) to very fine (0.125 mm), and were sub-angular to angular in shape.

Fines comprised approximately 21% of the sample by weight, with an overall color most closely matching Munsell pale yellow (2.5Y 8/2).

There were no lime blebs in the sample; strong gas evolution upon addition of acid to the sample indicated a moderate to high lime content. Approximately 34% of the sample weight was acid soluble.

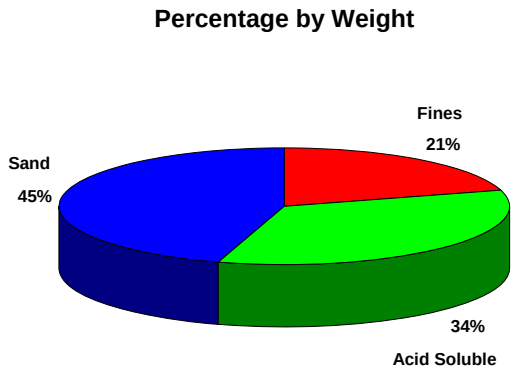


Figure 8: *Location of Sample M7 (left) from joint at the Tusha Hiti and chemical analysis data (right).*

3.3 Comments

All sand samples contained mica in some quantity, which may indicate a common source. Mica was also identified in both stone samples submitted for petrography, which were tentatively determined to be local. All sand samples also featured sub-rounded and/or sub-angular particles, which are commonly found in river sands. It is possible, then, that the sand used in all five mortars is a local river sand, which may have been modified for different campaigns with the addition of more or less brick particles and/or other additives. As coarser and finer aggregates were noted it is possible that some of the sands may have been screened which is more typical of modern mortars.

Sands from Sample M4 (from the north wall of the Bhandarkhal Tank) and Sample M7 (from the Tusha Hiti) are remarkably similar in appearance as both feature primarily white and clear grains, mica fragments and a few brick particles, and fines of a similar light (Munsell white or pale yellow) color. Both samples also have similar compositional ratios by weight (Sample M4: 55% sand, 15% fines, 30% acid soluble; Sample M7: 45 % sand, 21% fines, 34% acid soluble). These similarities likely indicate that the mortars are from the same campaign, which appears to post-date 1957 based on dating of Sample M4, noted previously.

It appears that the mortar samples tested by wet chemical analysis in this scope of work represent what's been done in limited areas on the surface of the monuments in the last 75 years. Further study would require deeper probes into the joints to potentially extract any original mortars, if extant.

4. ION ANALYSIS

Ion analysis is conducted to identify and measure salts in a given sample, as salt identification can help determine possible sources. For example, sulfates can come from fertilizers, occur naturally in some brick, or can form as a byproduct of acid rain and calcium-carbonate based stones; nitrates can come from guano or fertilizer; phosphates can come from decomposed organic matter, soaps, or fertilizer; carbonates can come from lime-based mortar.

Samples selected for testing include the following, by area:

- Dui Maju Shrine: one mortar sample (M1)
- Bhandarkhal Tank and Pavilion: four efflorescence samples (A1, A2, A3, and A4) and one mortar sample (M5)
- Tusha Hiti: one efflorescence sample (A5)

Testing for the presence of calcium, nitrates, phosphates, and sulfates was done using EM Quant Quantitative ion-specific test strips. Additional testing for solubility in water and the presence of calcium, carbonates, and sulfates was completed using chemical spot tests.

4.1 Methodology

4.1.1 Quantitative Strips

Samples were extracted and tested for calcium, nitrates, phosphates, and sulfates using ion specific quantitative test strips. A set amount of each sample was powdered, mixed with a set amount of de-ionized water, and allowed to sit for 24 hours. The test strips were dipped into the sample solution. The concentration of the specific ion causes the reaction zones on the test strip to change color. The test strips were compared to the color chart in the product literature and any color change, indicating the presence of the specific ion, and corresponding concentration was noted.

Testing for solubility in water and the presence of calcium, carbonates, and sulfates was completed using chemical spot tests.

4.1.2 Chemical Spot Tests

Samples were tested for solubility in water by using de-ionized water, which was added to the samples. Samples were then monitored over a two minute period to determine if all or a portion of the sample was dissolved by water.

As the lowest possible reading on the calcium strip test is 0-10 mg/l, a supplemental chemical spot test for the presence of calcium was conducted. This spot test involved adding several drops of 3M nitric acid to the sample to put into solution. A drop of this solution was placed on a glass slide and allowed to dry. Once dry, a drop of 2M sulfuric acid was applied to the solution. The formation of gypsum (calcium sulfate) needles indicates the presence of calcium in the solution.

Samples were tested for the presence of the carbonate ion using several drops of 3M hydrochloric acid, which were added to the samples. Samples were monitored for the evolution of bubbles, a positive indication of the carbonate ion.

Because the lowest possible reading on the sulfate strip test is <200 mg/l, which includes all results from 0-199 mg/l, a supplemental chemical spot test for the presence of sulfates was conducted. This spot test involved adding several drops of 3M hydrochloric acid followed by one drop of 0.3M barium nitrate to each sample. White precipitate indicates the presence of sulfates.

4.2 Findings

Results of ion analysis are summarized by sample location below.

4.2.1 Dui Maju Shrine

Dui Maju Shrine						
No.	**Carbonate spot test (+/-)**	**Calcium strip test (mg/l)**	**Calcium spot test (+/-)**	**Sulfate strip test (mg/l)**	**Nitrate strip test (mg/l)**	**Phosphate strip test (mg/l)**
M1	**+** (strong eff.)	25	**+**	200-400	100-250	15

4.2.1.1 Mortar Sample M1

Mortar Sample M1 was extracted from the joint at the top of the shrine. This sample was found not to be highly soluble in water. The sample tested positive for carbonates, calcium and sulfates, which likely indicates the presence of calcium carbonate, likely a component of the mortar, and gypsum (calcium sulfate dihydrate). Gypsum is a common by-product of acid rain and calcium carbonate-based material. Gypsum is slightly water soluble and is therefore usually found in areas which are shielded from rainwater. Though a lack of water solubility was noted in the tested sample, this does not necessarily rule out the presence of gypsum, as gypsum requires a prolonged exposure to water in order to solubilize. The sample also tested positive for nitrates and phosphates.

Figure 9: *Location of Sample M1 (left) from the top of the Dui Maju Shrine and detail of sample (right).*

4.2.2 Bhandarkhal Tank and Pavilion

Bhandarkhal Tank and Pavilion								
No.	Carbonate spot test (+/-)	Calcium strip test (mg/l) 1st Trial	Calcium strip test (mg/l) 2nd Trial	Calcium spot test (+/-)	Sulfate strip test (mg/l)	Sulfate spot test (+/-)	Nitrate strip test (mg/l)	Phosphate strip test (mg/l)
A1	–	10-25		+	400-800		100-250	15
A2	+ (strong eff.)	0-10	10-25	+	<200	–	0-10	5-15
A3	–	0	0-10	+	>1600	+	100-250	15
A4	–	100			200-400	+	500	5-15
M5	+ (strong eff.)	10		+	200-400		50-100	15

4.2.2.1 Efflorescence Sample A1

Efflorescence Sample A1 was extracted from the west corner stone of the pavilion exterior. It was found not to be highly soluble in water and tested negative for carbonates. The sample tested positive for calcium and sulfates, which may indicate the presence of gypsum. The sample also contained some nitrates and phosphates.

Figure 10: *Location of Sample A1 (left) from the exterior of the Bhandarkhal Tank pavilion and detail of sample (right).*

4.2.2.2 Efflorescence Sample A2

Efflorescence Sample A2 was extracted from a mortar surface on the interior of the pavilion. Sample A2 was found not to be highly soluble in water. Carbonates, calcium and only a very small amount of sulfates were found in the sample, which likely indicates the presence of calcium carbonate and possibly a very small amount of gypsum. A small amount of nitrates and some phosphates were also found in the sample.

Figure 11: *Location of Sample A2 (left) from the interior of the Bhandarkhal Tank pavilion and detail of sample (right).*

4.2.2.3 Efflorescence Sample A3

Efflorescence Samples A3 was extracted from the stone surface on the interior of the pavilion. The sample contained a mix of salt efflorescence with some crust. Sample A3 was highly water soluble, contained the highest concentration of sulfates out of all samples and did not contain carbonates. Only a very small amount of calcium was found, but a high concentration of sulfates was observed, likely indicating that the salt is not gypsum but some other sulfate compound. Some nitrates and phosphates were also found in the sample.

Figure 12: *Location of Sample A3 (left) from the interior of the Bhandarkhal Tank pavilion and detail of sample (right).*

4.2.2.4 Efflorescence Sample A4

Efflorescence Sample A4 was extracted from the east wall on the exterior of the pavilion. The sample was not highly soluble in water and tested negative for carbonates. The sample tested positive for calcium and sulfates, which may indicate the presence of gypsum. The sample also contained a large amount of nitrates and some phosphates.

Figure 13: *Location of Sample A4 (left) from the exterior of the Bhandarkhal Tank pavilion and detail of sample (right).*

4.2.2.5 Mortar Sample M5

Mortar sample M5 was extracted from the north wall under the pavilion, from mortar that is said to date to 1957. This mortar was also used for repairs of carvings on the pavilion. The sample was found not to be highly soluble in water. The sample tested positive for carbonates, calcium and sulfates. Sample M5 also contained some nitrates and phosphates.

Figure 14: *Location of Sample M5 (left) from the north wall of the Bhandarkhal Tank just below the pavilion and detail of sample (right).*

4.2.3 Tusha Hiti

Tusha Hiti						
	Carbonate spot test (+/-)	**Calcium strip test (mg/l)**	**Sulfate strip test (mg/l)**	**Sulfate spot test (+/-)**	**Nitrate strip test (mg/l)**	**Phosphate strip test (mg/l)**
A5	**–**	0	200-400	**+**	0-10	5-15

4.2.3.1 Efflorescence Sample A5

Efflorescence Sample A5 extracted from the east side of the Tusha HIti. It was not highly soluble in water and tested negative for carbonates and calcium. Some sulfates were observed, likely indicating that the salt is not gypsum but some other sulfate compound. A small amount of nitrates and some phosphates were also identified.

Figure 15: *Location of Sample A5 (left) from the east side of the Tusha Hiti and detail of sample (right).*

4.3 Comments

The dominant salts (semi-quantitatively) in all samples appear to be sulfates and nitrates. The sulfates could be from two sources. One would be from the Portland cement in the mortars due to the addition of sulfates during the manufacturing of the cement. The other source might be the sulfation (typically as gypsum or calcium sulfate dihydrate) of calcium carbonate in the lime-based mortars which is due to sulfur trioxide as a pollutant gas. The sulfates can be transferred to other surfaces (such as the surrounding stone) due to leaching from rain water.

As far as the other ions, nitrates most typically will be from guano or animal scat (usually as potassium nitrate); all samples that tested positive for carbonates were taken from a mortar surface or were a mortar sample which explains the presence of the ion; and lastly, all samples had small amount of phosphates which could be attributed to the decomposition of organic matter.

Often water solubility determines a recommendation for salt removal methods. Highly soluble salts will usually be removed with poultices; however, the slightly soluble to insoluble salts typically require mechanical action for removal, such as microabrasion.

5. FOURIER TRANSFORM INFRARED SPECTROSCOPY

5.1 Methodology

FTIR spectroscopy is a tool to characterize organic and inorganic molecules. An infrared beam is directed at the sample and the sample's response is monitored. The energy is transmitted through, reflected off, or absorbed by constituent compounds at a rate that is characteristic of each compound. The frequencies are recorded, measured, and translated into a spectrum that represents particular molecular transmissions, reflections or absorptions which are unique to each compound. The analysis thus creates a molecular fingerprint of the sample.

Samples selected for testing include the following, by area:

- Bhandarkhal Tank and Pavilion: one coating sample (C1), one mortar sample (M8), and two stone samples (S2 and S3)
- Tusha Hiti: one coating sample (C2)

These samples were sent to an independent laboratory for analysis. A synopsis is provided below; for the complete report refer to separate document titled FTIR Report, dated November 19, 2008, submitted by Orion Analytical LLC. Analysis was directed at identifying organic compounds which might indicate the presence of a coating left from past interventions.

5.2 Findings

5.2.1 Bhandarkhal Tank and Pavilion

5.2.1.1 Coating Sample C1

Sample C1 included a portion of stone with a visible clear coating that was extracted from the Bhandarkhal Tank. The clear coating on the surface was identified as polyvinyl acetate (possibly used here as a consolidant, which was a typical method in the 1960s to 1980s).

Figure 16: *Location of Sample C1 (left) at the Bhandarkhal Tank and detail of sample with visible coating (right)*

5.2.1.2 Mortar Sample M8

Mortar Sample M8 was extracted from cement repair mortar on carving at the pavilion. The sample contained a visible clear coating visible on the surface, which was found to include a mixture of materials such as protein, long-chain aliphatic hydrocarbon material(s) (e.g paraffin wax, possibly used as a consolidant or water repellent treatment), and polyvinyl acetate (possibly used as a consolidant). Also noted were quartz, gypsum, and an unidentified component (same as that found in Sample S2).

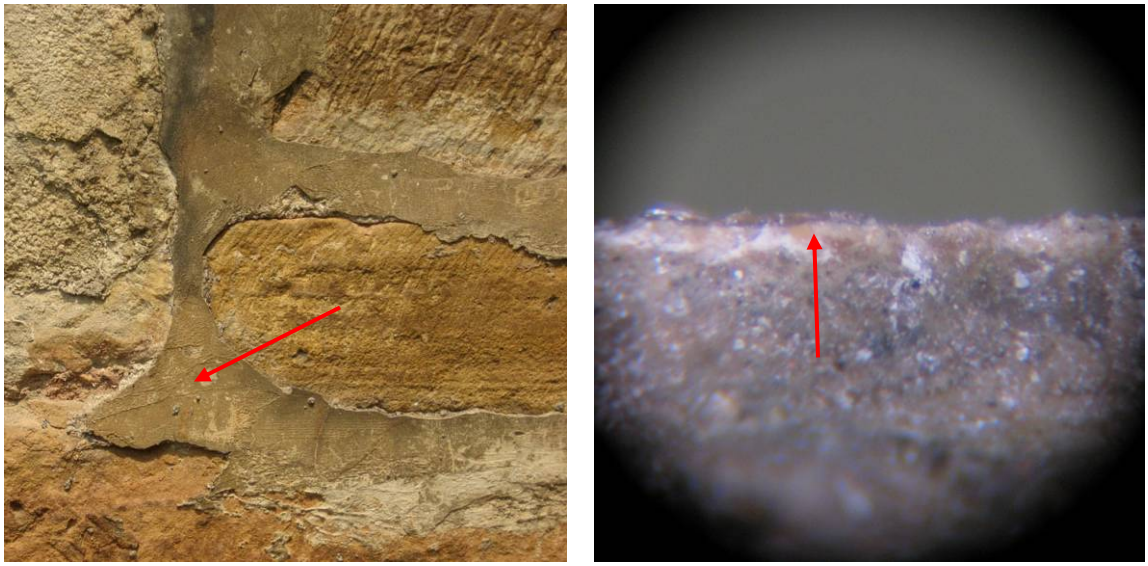


Figure 17: *Location of Sample M8 (left) at the Bhandarkhal Tank and detail of sample with visible coating (right).*

5.2.1.3 Stone Sample S2

Stone Sample S2 was extracted from the niche on the north wall of the tank, under the pavilion. A surface scraping of Sample S2 revealed a mixture of materials, including gypsum and the same unidentified component detected in Sample M8. In a chloroform soluble extract from Sample S2, long-chain aliphatic hydrocarbon material(s) (which could be, for example, paraffin wax possibly used as a consolidant or water repellent treatment) were identified.

Figure 18: *Location of Sample S2 (left) at the Bhandarkhal Tank and detail of sample (right).*

5.2.1.4 Stone Sample S3

Stone Sample S3 was extracted from the west wall of the Bhandarkhal Tank, within an area of visible ferrous staining. A surface scraping from Sample S3 contained a mixture of materials, including quartz and additional silicate material(s). In a chloroform soluble extract from Sample S3, long-chain aliphatic hydrocarbon material(s) (which could be, for example, paraffin wax possibly used as a consolidant or water repellent treatment) were identified.

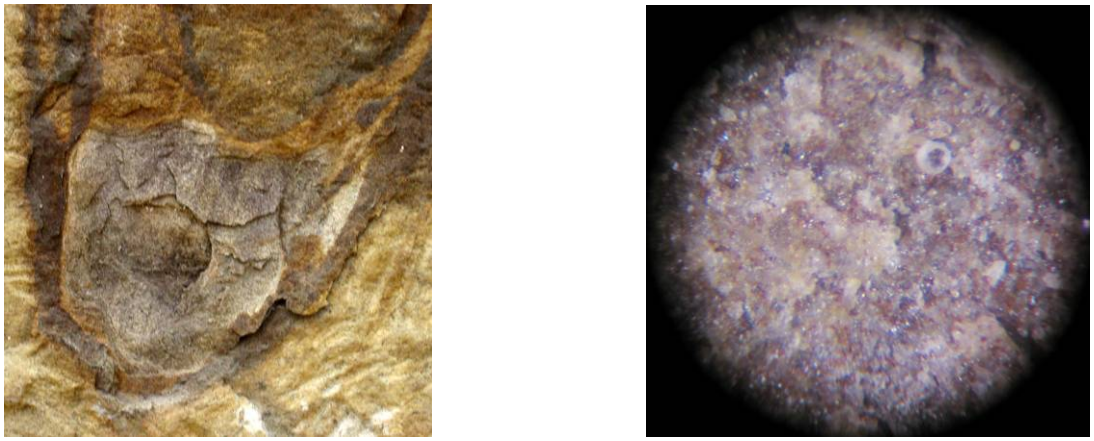


Figure 19: *Location of Sample S3 (left) at the Bhandarkhal Tank and detail of sample (right).*

5.2.2 Tusha Hiti

5.2.2.1 Coating Sample C2

Coating Sample C2 was extracted from black deposits on the east side of the Tusha Hiti. The black coating in Sample C2 contained a mixture of materials, including unidentified protein, quartz, and additional silicate material(s).

Figure 20: *Location of Sample C2 (left) at the Tusha Hiti and detail of sample (right).*

5.3 Comments

It is evident from the findings that past treatments were most likely applied to the select areas tested within this scope. These treatments will have to be considered when determining recommendations for conservation of the stone.

6.0. RECOMMENDATIONS

As suggested by the results of the testing conducted, additional testing and a hands-on unit-by-unit survey of the elements investigated herein are necessary. The tests indicate several mortar campaigns are extant (applied most likely in the last 75 years), many different ions are present in the same and varying architectural elements, at least two different stones are identified and not all architectural elements were included in the sampling, and many organic compounds were seen in the coatings, stones and mortars. Without a conditions survey and further testing, the source of these organic and inorganic compounds cannot be known. Additionally, several of the compounds found can inhibit effective conservation treatments thus their locations and extents should be documented.

APPENDIX A: MORTAR ANALYSIS WORKSHEETS

MORTAR ANALYSIS WORKSHEET
Royal Palace, Patan, Nepal

SAMPLE # M2

GENERAL INFORMATION

Joint width:		Masonry:		Date sampled:	04/29/08
Joint profile:		Location:	Bhandarkhal Tank	Date analyzed:	09/22/08
			"Wall under pavilion from joint, repair from 2007"		

VISUAL ANALYSIS:

Surface appearance:	exterior surface not identifiable		
Cross section appearance:	average mix of sand and binder, salts visible		
Color:	light gray		
Munsell:	5Y 7/1		
Binder color:	white		
Hardness:			
Lime clumps?	no	Organic matter?	no

CHEMICAL ANALYSIS, INPUT SECTION

Beaker weight:	230.30	Beaker with sands weight:	230.57
Beaker w/sample weight:	230.97	Filter paper w/fines weight:	2.995
Gross sample weight:	0.67	HCl Reaction:	vigorous
Filter paper weight:	2.82	Filtrate Color:	clear, very pale yellow

Notes/Observations:

COMPOSITION ANALYSIS:

	WEIGHT	WEIGHT %	WEIGHT RATIO
FINES	0.18	26.28%	1.0
ACID-SOLUBLES	0.23	33.78%	1.3
AGGREGATE	0.27	39.94%	1.5

SANDS:

Sieve Size	Grams Retained	% Retained:
4	0.00	0%
8	0.00	0%
16	0.00	0%
30	0.00	0%
50	0.00	0%
100	0.00	0%
PAN	0.00	0%
TOTAL	0.00	0%

Grain Shapes:	subangular - subrounded
Grain Colors:	white, yellow, black, orange, mica
Overall color:	gray
Munsell:	2.5Y 6/1
Grain size:	very fine to fine
Size range:	1/8mm - 1/4mm

FINES: Color: light greenish gray Munsell: GLEY1 7/10Y

MORTAR ANALYSIS WORKSHEET
Royal Palace, Patan, Nepal

SAMPLE # M3

GENERAL INFORMATION

Joint width:		Masonry:		Date sampled:	04/29/08
Joint profile:		Location:	Bhandarkhal Tank "Suki mortar, probably ca. 1934"	Date analyzed:	09/22/08

VISUAL ANALYSIS:

Surface appearance:	heavily soiled, exposed aggregate		
Cross section appearance:	large aggregate with some brick fragments, large white particles - lime?		
Color:	warm tan		
Munsell:	7.5YR 7/3		
Binder color:	pink		
Hardness:	soft		
Lime clumps?	yes	Organic matter?	no

CHEMICAL ANALYSIS, INPUT SECTION

Beaker weight:	214.59	Beaker with sands weight:	218.67
Beaker w/sample weight:	220.16	Filter paper w/fines weight:	3.415
Gross sample weight:	5.57	HCl Reaction:	extremely vigorous
Filter paper weight:	2.81	Filtrate Color:	clear, pale yellow

Notes/Observations:

COMPOSITION ANALYSIS:

	WEIGHT	WEIGHT %	WEIGHT RATIO
FINES	0.61	10.94%	1.0
ACID-SOLUBLES	0.88	15.84%	1.4
AGGREGATE	4.08	73.21%	6.7

SANDS:

Sieve Size	Grams Retained	% Retained:
4	0.00	0%
8	0.00	0%
16	0.00	0%
30	0.00	0%
50	0.00	0%
100	0.00	0%
PAN	0.00	0%
TOTAL	0.00	0%

Grain Shapes:	subangular
Grain Colors:	clear, white, black, brick, mica
Overall color:	brown
Munsell:	7.5YR 5/3
Grain size:	fine - very coarse
Size range:	1/4mm - 2mm

FINES: Color: reddish yellow Munsell: 7.5YR 6/6

MORTAR ANALYSIS WORKSHEET
Royal Palace, Patan, Nepal

SAMPLE # M4

GENERAL INFORMATION

Joint width:		Masonry:		Date sampled:	04/29/08
Joint profile:		Location:	Bhandarkhal Tank "North wall first level joint"	Date analyzed:	09/22/08

VISUAL ANALYSIS:

Surface appearance:	exposed aggregate		
Cross section appearance:	rich mix with large and fine aggregate		
Color:	light gray		
Munsell:	2.5Y 7/2		
Binder color:	cream		
Hardness:	very hard		
Lime clumps?	no	Organic matter?	yes

CHEMICAL ANALYSIS, INPUT SECTION

Beaker weight:	205.19	Beaker with sands weight:	206.51
Beaker w/sample weight:	207.61	Filter paper w/fines weight:	3.2
Gross sample weight:	2.42	HCl Reaction:	vigorous
Filter paper weight:	2.84	Filtrate Color:	clear, yellow

Notes/Observations:

COMPOSITION ANALYSIS:

	WEIGHT	WEIGHT %	WEIGHT RATIO
FINES	0.36	14.72%	1.0
ACID-SOLUBLES	0.74	30.47%	2.1
AGGREGATE	1.33	54.82%	3.7

SANDS:

Sieve Size	Grams Retained	% Retained:
4	0.00	0%
8	0.00	0%
16	0.00	0%
30	0.00	0%
50	0.00	0%
100	0.00	0%
PAN	0.00	0%
TOTAL	0.00	0%

Grain Shapes:	subangular
Grain Colors:	white, clear, black, brick, mica
Overall color:	light gray
Munsell:	2.5Y 7/1
Grain size:	fine - coarse
Size range:	1/4mm - 1mm

FINES: Color: white Munsell: 2.5Y 8/1

MORTAR ANALYSIS WORKSHEET
Royal Palace, Patan, Nepal

SAMPLE # M6

GENERAL INFORMATION

Joint width:		Masonry:		Date sampled:	04/29/08
Joint profile:		Location:	Tusha Hiti	Date analyzed:	09/22/08
			"From left corner of center decoration field, repair of carvings"		

VISUAL ANALYSIS:

Surface appearance:	soiled, salts		
Cross section appearance:	rich mix		
Color:	gray		
Munsell:	2.5Y 6/1		
Binder color:	light gray		
Hardness:			
Lime clumps?	yes	Organic matter?	no

CHEMICAL ANALYSIS, INPUT SECTION

Beaker weight:	215.07	Beaker with sands weight:	215.08
Beaker w/sample weight:	215.15	Filter paper w/fines weight:	2.882
Gross sample weight:	0.08	HCl Reaction:	slight effervescence
Filter paper weight:	2.86	Filtrate Color:	clear

Notes/Observations:

COMPOSITION ANALYSIS:

	WEIGHT	WEIGHT %	WEIGHT RATIO
FINES	0.02	21.95%	1.0
ACID-SOLUBLES	0.05	60.98%	2.8
AGGREGATE	0.01	17.07%	0.8

SANDS:

Sieve Size	Grams Retained	% Retained:
4	0.00	0%
8	0.00	0%
16	0.00	0%
30	0.00	0%
50	0.00	0%
100	0.00	0%
PAN	0.00	0%
TOTAL	0.00	0%

Grain Shapes:	angular - subangular
Grain Colors:	clear, white, black, mica
Overall color:	white
Munsell:	5Y 8/1
Grain size:	very fine - coarse
Size range:	1/8mm - 1mm

FINES: Color: pale yellow Munsell: 2.5Y 8/2

MORTAR ANALYSIS WORKSHEET
Royal Palace, Patan, Nepal

SAMPLE # M7

GENERAL INFORMATION

Joint width:		Masonry:		Date sampled:	04/29/08
Joint profile:		Location:	Tusha Hiti "Joint mortar"	Date analyzed:	09/22/08

VISUAL ANALYSIS:

Surface appearance:	heavy soiling		
Cross section appearance:	rich mix		
Color:	white		
Munsell:	5Y 8/1		
Binder color:	white		
Hardness:			
Lime clumps?	no	Organic matter?	no

CHEMICAL ANALYSIS, INPUT SECTION

Beaker weight:	213.93	Beaker with sands weight:	214.17
Beaker w/sample weight:	214.47	Filter paper w/fines weight:	2.963
Gross sample weight:	0.54	HCl Reaction:	vigorous
Filter paper weight:	2.85	Filtrate Color:	clear, pale yellow

Notes/Observations:

COMPOSITION ANALYSIS:

	WEIGHT	WEIGHT %	WEIGHT RATIO
FINES	0.11	20.52%	1.0
ACID-SOLUBLES	0.18	34.20%	1.7
AGGREGATE	0.25	45.29%	2.2

SANDS:

Sieve Size	Grams Retained	% Retained:
4	0.00	0%
8	0.00	0%
16	0.00	0%
30	0.00	0%
50	0.00	0%
100	0.00	0%
PAN	0.00	0%
TOTAL	0.00	0%

Grain Shapes:	angular - subangular
Grain Colors:	white, clear, orange, black, brick, mica
Overall color:	light gray
Munsell:	10YR 7/1
Grain size:	very fine - coarse
Size range:	1/8mm - 1mm

FINES: Color: pale yellow Munsell: 2.5Y 8/2

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