
FINAL REPORT

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1. INTRODUCTION

The present work deals with the scientific research which was carried on for the architectural conservation of the tower T4 of the land walls of Constantinople at Yedikule within FORT-MED project and it is composed of the experimental works for the characterisation of the original materials, their deterioration processes and morphologies. Besides the properties of the repair materials were also researched to approve their appropriateness and compatibility for the historic fabric of the tower and the adjoining rampart. The land walls of the Constantinople were erected in the first half of the 5thC A.D, during the Theodosius II Era (408-450 A.D.). The rampart and the towers were subjected to a major reconstruction after the devastating earthquake in 740, some of the towers had also later interventions and especially the summit levels and the battlements of the towers and the rampart were repaired and reconstructed during the 15thC sieges. Thus, it can be clearly stated that there were at least three historical layers in the tower T4 and the rampart adjacent to it. The construction techniques also correlate with the chronological analysis based on the historical records and documents. photographs.

The experimental work included in the research programme aimed to evaluate the characterisation of the original materials and control the physical and mechanical properties of repair materials to match the original materials and not to cause a chemical contamination in the old fabric. According to the results of the experimental work it was concluded that the choices and the mixes of the mortars were fairly acceptable.
2. SAMPLING

The samples were taken from different parts of the tower 4 of land walls. These samples represented the 5th century (original parts), Medieval age (medieval reconstruction) and 15th century repairs. Before the last siege, the bricks and stones were sampled 5th century walls and the medieval reconstruction. There were only two kinds of natural stones and these were a chemically precipitated limestone and an organic limestone. Whereas the samples of the khorasan mortars were taken from the 5th century, medieval age and 15th century repairs. Consecutively, the mix designs were calculated and casted according to three different data matching the original recipes.

Figure 2.1. The ground level plan of the Tower 4 of the land walls of Istanbul
Figure 2.2. The upper level plan of the T4 of the land walls of İstanbul

Figure 2.3. The platform level plan of the T4 of the land walls of İstanbul
**Table 2.1. Sampling system of the stone, the brick and the mortar samples of T4 of land walls**

<table>
<thead>
<tr>
<th>No. of the Sample</th>
<th>Sample No</th>
<th>Elevation</th>
<th>Historical Period</th>
<th>Number of the Figure</th>
</tr>
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<tr>
<td>1</td>
<td>M1 / M8 / B5</td>
<td>+2.00 m</td>
<td>5th Century</td>
<td>Figure 2.5</td>
</tr>
<tr>
<td>2</td>
<td>M2</td>
<td>+2.00 m</td>
<td>5th Century</td>
<td>Figure 2.6</td>
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<td>Figure 2.8, 2.9</td>
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<tr>
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<td>+1.90 m</td>
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<tr>
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<td>Figure 2.16</td>
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<tr>
<td>11</td>
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<td>+19.50 m</td>
<td>15th Century</td>
<td>Figure 2.17</td>
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<tr>
<td>12</td>
<td>M15</td>
<td>+13.50 m</td>
<td>Medieval</td>
<td>Figure 2.18</td>
</tr>
<tr>
<td>13</td>
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<td>+14.00 m</td>
<td>Medieval</td>
<td>Figure 2.19</td>
</tr>
<tr>
<td>14</td>
<td>M18</td>
<td>+19.00 m</td>
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<td>Figure 2.20, 2.21, 2.22</td>
</tr>
<tr>
<td>15</td>
<td>B1</td>
<td>+19.20 m</td>
<td>Medieval</td>
<td>Figure 2.22</td>
</tr>
<tr>
<td>16</td>
<td>B2</td>
<td>+14.00 m</td>
<td>Medieval</td>
<td>Figure 2.23</td>
</tr>
<tr>
<td>17</td>
<td>S7</td>
<td>+20.00 m</td>
<td>Medieval</td>
<td>Figure 2.24</td>
</tr>
<tr>
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<td>S8</td>
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<tr>
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<td>Figure 2.27</td>
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<tr>
<td>20</td>
<td>S10</td>
<td>+3.50 m</td>
<td>Medieval</td>
<td></td>
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</tbody>
</table>

*Figure 2.4. The section of the Tower 4 (T4) of the land walls of Istanbul*

*M: Mortar samples, B: Brick samples, S: Stone samples*
The Photographs of Sampling

Samples; M1, M8, B5 (5th C)

Sample; M2 (5th C)

Samples; M3, B6 (Medieval)
Sample; M4 (Medieval)

Sample; M6 (Medieval)

Sample; M7 (5th C)

Sample; M7

Samples; M5,M9,B4 (Medieval)
Samples; M10, M11 (5th C)

Sample; M12 (5th C)

Sample; M15 (Medieval)

Samples; M16, M17, B3

Sample; M14, S8

Sample; M13 (5th C)
3. EXPERIMENTAL WORK

Most of the experimental works were conducted in the three laboratories of Istanbul Technical University. The test for the characterisation of the samples by means of simple and sophisticated techniques were conducted in the Material Testing lab. of the Faculty of Architecture, laboratory of the Metallurgy and Material Eng. of the Faculty of Chemical Eng., and the petrographic analysis tests were conducted in the petrography laboratory of the Geology Department of the Faculty of Mining, the physical and mechanical properties were determined in the Material Testing laboratory of the Faculty of Architecture.

3.1.1. Chemical Analysis,

3.1.2. Petrographic analysis : Acid Loss and Sieve Analysis, Ignition Loss Analysis, Petrographic Analysis (Thin sections), Qualitative and Semi-Quantitative Analysis of the Water Soluble Salts, ICP, DTA, SEM-EDX, Stereo-Optical Microscopy, Porosimetry (Mercury Intrusion)…


3.1.4. Mechanical Properties : Compressive Strength, Tensile Strength, Point Load Test…..
Results of the visual, macro and micro inspections, DTA-TG, X-Ray diffraction and SEM-EDX analysis of the mortar, brick and the stone samples

The samples were ground and powdered and sieved (0.297 mm mesh size), and regarding to ASTM 50, XRD and DTA tests were conducted. For the visual inspections the samples were imbedded in epoxy resin, and polished. The heating rate for the DTA was chosen as 10 °C/min. The original surfaces of the samples were inspected without any preparation. The samples were covered with carbon for SEM, semi-quantitative analysis and inspected at 15KV with EDXA, they were scanned at the back scatter mode. The brick samples were taken to bakalite and polished mechanically for the macro inspections.

Sample: T4 Khorasan mortar- 5th Century

The Visual Analysis:
The sample was weak and crumbling, and it had micro cracks

Figure 3.1. The microstructure of 5th C. mortar sample and under stereo microscope

Figure 3.2. The XRD diagram of sample 5th C. mortar and under stereo microscope
The results of the DTA Analysis:

The DTA curve of the sample 5thC showed a wide endothermic DTA peak in between 675 °C to 756° C which was decomposition of CaCO₃, followed by small DTA peak at 573 °C which was the conversion of α-quartz to β-quartz.

Figure 3.3. The DTA curve of sample 5th century mortar and medieval mortar sample
The back scattering EDX analysis indicated that the surface cracks of the sample 5\textsuperscript{th} C contained barium sulphate with less amount (rarely) of strontium. It also contained some chlorine salt.

*Figure 3.4. The EDX spectrum of the sample 5\textsuperscript{th} C.*

*Figure 3.5. The EDX spectrum of the sample 5\textsuperscript{th} C.*
Sample: T4 Khorasan Mortar – Medieval

The Visual Analysis:

The constituents (BP) and decomposition products of the medieval khorasan mortar sample. The surface properties of medieval mortar sample were shown below.

Figure 3.6. The medieval mortar’s structure in stereo microscope (a) Mortar (b) Brick pieces
The results of the X-Ray Diffraction:

XRD-spectrum of sample indicated that the main composition of sample was $\alpha$-quartz and CaCO$_3$.

The results of the DTA:

DTA peaks in between 700°C - 744°C and 781°C indicate the endothermic peaks of decomposition of CaCO$_3$ of the sample.

Figure 3.7. (a,b) The EDX- spectra of the medieval mortar sample
Sample M14- 15th Century Khorasan Mortar

The Visual Analysis:

The crumbling sample M14 exhibited a dirty surface, lime lumps and yellow minerals were seen in the matrix and the brick pieces, were very rare.

The DTA curve indicated a large endothermic carbonate decomposition peak at 831°C.

Figure 3.8. The alteration on the dirty surface of the mortar sample M14

Figure 3.9. The EDX spectrum of the mortar sample M14
Sample: Brick – 5th Century

The Macro Analysis:

The brick sample was composed by micro clay minerals and various rock particles as additives.

Figure 3.10. The macro structure of 5th century brick

Figure 3.11. The EDX diagram of the sample of 5th century brick
Sample: Brick – Medieval

The Macro Analysis:

The brick sample was composed of micro clay minerals and various rock particles as additives.

Figure 3.12. (a) and (b), The macrostructure of the medieval brick sample
The Micro Analysis:

Regarding to the micro analysis of the medieval brick sample, its constituents were clay with lime, it also contained salt and sulphate.

Figure 3.13. (a,b) The EDX spectra of the medieval brick sample
Sample: Chemically Precipitated Limestone

The Macro Analysis:

The sample had pores and secondary calcite crystals.

Figure 3.14. The macro structure of the chemically precipitated limestone, (a) Secondary calcite crystals, (b) Pores
**The Micro Analysis:**

The microanalysis were carried on the original and the broken surfaces. The SEM-EDX results of the broken surface indicated 7 μm sized impurity particles contained Cr, Fe, N, and Zn while the salt crystals were observed on the original surface. The yellow colour of the sample was given by the iron hydroxide, Fe(OH)$_2$.

*Figure 3.15. (a,b) The EDX spectra of the chemically precipitated limestone*
Sample: Organic Limestone (Kufeki Stone)

The Macro Analysis:

The macro structure had secondary calcite crystals. The SEM micrographs and the EDX analysis showed calcium rich hexagonal prisms.

The Micro Analysis:

The micro analysis indicated the rare 5-10μm sized manganase and chromite impurities.

Figure 3.16. The micro analysis with stereo microscope

(a)
Organic Limestone (Kufeki Stone)

Figure 3.17. (a,b,c) The EDX-spectra of the Kufeki stone (organic limestone)
Sample: M17 - Medieval Khorasan Mortar

The mortar sample M17 was a lime mortar with coarse crushed brick aggregates. The adhesion between aggregate-binder interstices was very good. The aggregate-binder interphase and the products of the deterioration processes of the aggregates and the matrix.

Figure 3.18. Sample M17, (a) Aggregate-matrix interphase, (b) The aggregate, (c) The lime matrix
The Micro Analysis:

Figure 3.19. (a,b) The EDX spectra of the mortar sample M17
Sample: B1 – Medieval Brick

Fine and yellow ochre coloured structure with iron minerals. The DTA curve indicated two small endothermic peaks. Quartz transformation at 572°C and molecular water loss at 665°C.

*Figure 3.20. (a,b) The macrostructure of the medieval brick sample B1*
Figure 3.21. The XRD diagram of the brick
The Micro Analysis of Medieval Brick:

**Figure 3.22.** The EDX-spectrum of the brick sample B1

**Figure 3.23.** The DTA curves of S10 (medieval stone), Kufeki 4 (organic limestone) and B1 (medieval yellow ochre coloured brick)
Sample: S8 – Medieval Stone

The sample S8 was similar to samples S7, S9 and had a porous layer on the surface of the CaCO3 layer and fine biotites in the matrix.

(a) Surface, (b) Porous layer, (c) Secondary calcite formation in the interstice between the porous layer

Figure 3.24. The micro structure of S8 (medieval stone)
The Micro Analysis of S8 – Medieval Stone:

Figure 3.25. The EDX diagram of S8

Figure 3.26. Inner and outer surface of stone sample S8 has precipitated calcareous layers, (EDX diagram)
3.1.2. The Petrographic Analysis of the Natural Building Stones, Bricks and the Mortars

Stone 1: The sample is a microcrystalline limestone which contains 99% micrites and cryptocrystalline carbonate mud, and, 1% opaque iron oxide (Fe₂O₃) minerals. The pellets, indicates the ripple medium, and the size differentiated particle zoning and pseudo oolites were observed in the thin section, Figure 3.27.

Stone 2: The sample is similar with stone 1. It additionally has 1% quartz, 1-2% opaque iron oxide minerals and 1-2% pores, Figure 3.28.

Figure 3.27. The micritic limestone with pseudo oolithes, (Stone 1 and 4)

Figure 3.28. The micritic limestone which contains large calcite crystals, (Stone 2)
**Stone 3**: The sample is a microcrystalline limestone that contains calcites with cryptocrystalline-microcrystalline size, 1-2% of opaque minerals, and, large amount pores. Most of the pores were filled with the secondary calcite minerals and lesser amount of the pores were filled with secondary clay and chlorite minerals, Figure 3.29a, Figure 3.29b.

![Figure 3.29](a) Smaller calcite and opaque minerals (single nicole), (b) Double nicole, (Stone 3)

**Stone 4**: The sample is a microcrystalline limestone which contains 99% micrites and cryptocrystalline carbonate mud, and, 1% opaque ironoxide (Fe2O3) minerals. The pellets, indicates the ripple medium, and the size differentiated particle zonning and pseudo oolites were observed in the thin section, Figure 3.27.
**Stone 5:** The sample is a fossiliferous microcrystalline limestone that contains 70 % of micrites and fossils. Approximately 30 % of the secondary large calcite crystals formed in the pores of the mass, and, at the boundaries and inside of the shell fragments, Figure 3.30.

**Stone 6:** The sample is a marble that contains mainly calcite and seldom dolomite crystals. The sizes of calcite crystals ranged in 0.1-2.0 mm and cumulated between 0.1-0.6 mm. The sizes of the dolomite crystals were even smaller than the calcite crystals, Figure 3.31.

*Figure 3.30.* The cryptocrystalline fossiliferous limestone with micrites and secondary calcites, (Stone 5)

*Figure 3.31.* The large calcite crystals in marble, (Stone 6)
**Stone 7**: The sample is a cryptocrystalline calcitic and fossiliferous microcrystalline limestone. The secondary large calcite crystals which different from the calcite binder, at the pores and at the boundaries of the fossils. The sample contains 1 % chlorite and iron oxide spots at the boundaries of the shell fragments, and, 1 % opaque minerals, Figure 3.32.

![Figure 3.32. A limestone with micrites and recrystallized part, (Stone 7)](image)

**Stone 8**: The sample is a fossiliferous microcrystalline limestone with excessive amount of fossils. It has also another amorphous zones with excessive amount of fossils and some stone particles (limestone particles with and without clay and sand, altered granite particles), feldspar (orthoclase) and quartz in an organic binder. The stone totally has 2 % of opaque minerals, Figure 3.33, Figure 3.34, Figure 3.35.

![Figure 3.33. The limestone particle with numilite fossils, (Stone 8)](image)  ![Figure 3.34. The limestone, fossil, and, sound and altered orthoclase particles,](image)  ![Figure 3.35. The rounded limestone particle, (Stone 8)](image)
**Stone 9**; The sample is a limestone that contains microcrystalline calcite, lesser amount shell fragments, 0.5-1 % opaque minerals, and, 3-5 % pores. The calcite crystals in the sample were well crystallized, homogenously distributed, and, had no alteration. The sizes of these calcite crystals were below 0.3 mm, Figure 3.36.

![Stone 9](image)

*Figure 3.36. The tough calcite crystals and opaque minerals, (Stone 9)*

**Stone 10**; The sample is a microcrystalline limestone that contains calcites with cryptocrystalline-microcrystalline size, 1-2 % of opaque minerals, and, large amount pores. Most of the pores were filled with the secondary calcite minerals and lesser amount of the pores were filled with secondary clay and chlorite minerals.
**Brick 1**: The brick sample has 15% stone and mineral particles. Most of the particles with the sizes smaller than 0.1 mm were quartz and feldspar minerals. A few ones having the sizes around 0.5 mm were quartz, partly altered feldspar, mica minerals and limestone particles, Figure 3.37, Figure 3.38, Figure 3.39.

![Figure 3.37. The quartz and feldspar particles in clay matrix, (Brick 1)](image1)

![Figure 3.38. The slightly altered feldspar particle, (Brick 1)](image2)

![Figure 3.39. The altered orthoclase particle, (Brick 1)](image3)

**Brick 2**: The brick sample has 25% of stone particles and minerals in the whole thin section 75% is the clay. The stone particles, which are smaller than 0.5 mm, except a few 2.0 mm sized, ones were cryptocrystalline and microcrystalline limestone, granite and quartzite. Only some of the limestone particles and the feldspars partly altered. The minerals were orthoclase, plagioclase, quartz and very few amphiboles such as hornblende, Figure 3.40.

![Figure 3.40. Feldspar particle which is mostly altered, (Brick 2)](image4)
**Brick 3:** The brick sample has mostly granitic stone particles and lesser amounts of quartzite, limestone and sandy limestone particles. The minerals were orthoclase, quartz and a few partly altered muscovite.

**Brick 4:** The brick sample has similar properties with brick 2 sample. It has mostly granitic particles and lesser amounts of quartzite, limestone and sandy limestone particles. The minerals of the brick were quartz, a few muscovite and partially altered orthoclase, Figure 3.41, Figure 3.42.

*Figure 3.41. Partly altered alkaline orthoclase (off light), (Brick 4)*

*Figure 3.42. On light, (Brick 4)*
**Brick 5:** The brick sample has 20-22% stone particles and minerals, 3% opaque minerals, and, a few pores. The sizes of the stone particles were mostly cumulated in between 0.5-2.0 mm were granite, gneiss granite, quartzite, and sandstones with and without clay and carbonate inclusions. Most of the particles are smaller than 0.5 mm and only a few alkaline feldspar particles were around 3.0 mm. All of the types of the particles, except the quartzite were mostly or partially altered. The minerals were mostly orthoclase and a lesser amounts of plagioclase, Figure 3.43.

![Figure 3.43. The plagioclase mineral altered at the firing process, (Brick 5).](image)

**Brick 6:** The brick sample has 20-25% stone particles, 2-3% of opaque minerals and very little amount pores in the binder (72-78%). The sizes of the stone particles were mostly between 0.3-1.8 mm, they were granite, gneiss granite, quartzite, sandstone, sandy limestone and a few igneous stone particles. All the types of the particles, except quartzite were mostly or partially altered. Most of the particles were smaller than 0.3 mm. A few alkaline feldspars around 5.0 mm were also observed in the sample. Most of the minerals were partially altered orthoclase and lesser amounts of quartz and plagioclase, Figure 3.44, Figure 3.45.

![Figure 3.44.](image) Sound and altered plagioclases

![Figure 3.45. The feldspars as plagioclase, and opaque minerals as iron oxide](image)
The Petrographic Analysis of the 5th Century Mortar Samples:

**Figure 3.46.** Altered F particle size with ~250µ is in the binder, (Mortar 1)

**Figure 3.47.** The slightly altered quartzite particle with approximately 250µ size, (Mortar 2)

**Figure 3.48.** The phase between the brick piece and binder and the feldspar particles in the lime paste, (Mortar 2)
The Petrographic Analysis of the Medieval Mortar Samples:

Figure 3.49. The brick dusts and black particles (probably magnetite or hematite) in the binder, (Mortar 3)

Figure 3.50. The phase between the binder and the feldspar particle, (Mortar 4)

Figure 3.51. The altered feldspars due to carbonate formation, (Mortar 4)

Figure 3.52. The calcerous fossil, (Mortar 5)
The Petrographic Analysis of the 15th Century Mortar Samples:

*Figure 3.53. Altered orthoclase as domorite formation, (Mortar 16), medieval mortar sample*

*Figure 3.54. The limestone and the fossils, sample M14*
### 3.1.3. The Physical Properties of Natural Stones, Bricks and Mortars

*Table 3.1. The average results of physical property tests of stone and brick samples*

<table>
<thead>
<tr>
<th>Samples</th>
<th>CC</th>
<th>WA</th>
<th>WA</th>
<th>WA</th>
<th>D</th>
<th>SG</th>
<th>C</th>
<th>P</th>
<th>SD</th>
<th>μ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(gr/cm^2 √sn)</td>
<td>(m/m, %)</td>
<td>(v/v, %)</td>
<td>(m/m, %)</td>
<td>(g/cm^3)</td>
<td>(g/cm^3)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
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<td>Stone 5th C.</td>
<td>3.6*10^-4</td>
<td>2.57</td>
<td>5.98</td>
<td>4.71</td>
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<td>2.33</td>
<td>2.68</td>
<td>86.94</td>
<td>13.06</td>
<td>45.79</td>
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<tr>
<td>Stone Medieval</td>
<td>5.1*10^-4</td>
<td>3.70</td>
<td>7.67</td>
<td>6.74</td>
<td>13.40</td>
<td>2.23</td>
<td>2.66</td>
<td>82.58</td>
<td>17.42</td>
<td>59.35</td>
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<td>Brick 5th C.</td>
<td>3.1*10^-4</td>
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<td>35.68</td>
<td>23.29</td>
<td>36.93</td>
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<td>1.79</td>
<td>2.70</td>
<td>66.19</td>
<td>33.81</td>
<td>86.54</td>
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</table>

- **S**: Stone sample
- **B**: Brick sample
- **CC**: Coefficient of capillary
- **WA**: Water absorption
- **D**: Density
- **SG**: Specific gravity
- **C**: Composity
- **P**: Porosity
- **SD**: Saturation degree
- **μ**: Water vapour transmission
Table 3.2. The average results of physical property tests of mortar samples

<table>
<thead>
<tr>
<th>Samples</th>
<th>WA (m/m,%)</th>
<th>WA (v/v,%)</th>
<th>D (g/cm³)</th>
<th>SG (g/cm³)</th>
<th>C (%)</th>
<th>P (%)</th>
<th>SD (%)</th>
</tr>
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<tbody>
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<td>Mortar 15th C.</td>
<td>18.72</td>
<td>31.10</td>
<td>1.69</td>
<td>2.56</td>
<td>66.02</td>
<td>33.98</td>
<td>86.45</td>
</tr>
<tr>
<td>Mortar Medieval</td>
<td>27.55</td>
<td>40.38</td>
<td>1.46</td>
<td>2.46</td>
<td>61.35</td>
<td>38.65</td>
<td>100</td>
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<tr>
<td>Mortar 5th C.</td>
<td>18.18</td>
<td>30.91</td>
<td>1.71</td>
<td>2.59</td>
<td>64.40</td>
<td>35.60</td>
<td>88.71</td>
</tr>
</tbody>
</table>

S : Stone sample  
B : Brick sample  
WA : Water absorption  
D : Density  
C : Composity  
SG : Specific gravity  
P : Porosity  
SD : Saturation degree  
μ : Water vapour transmission
3.1.4. The Mechanical Properties of Natural Stones, Bricks and Mortars

Table 3.3. The average results of mechanical property tests of the stone and the brick samples

<table>
<thead>
<tr>
<th>Samples</th>
<th>Compressive Strength ((\sigma_c), N/mm(^2))</th>
<th>Tensile Strength ((\sigma_t), N/mm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone 5(^{th}) C.</td>
<td>25.3</td>
<td>7.06</td>
</tr>
<tr>
<td>Stone Medieval</td>
<td>21.15</td>
<td>5.5</td>
</tr>
<tr>
<td>Brick 5(^{th}) C.</td>
<td>14.9</td>
<td>4.3</td>
</tr>
<tr>
<td>Brick Medieval</td>
<td>19.21</td>
<td>5.4</td>
</tr>
</tbody>
</table>
**Point load test**: Since the original mortar samples were too weak, the mechanical properties could not be found by uniaxial compressive strength test. So, the compressive strengths of the original mortar samples were determined by conducting the point load method and the results were converted to uniaxial compressive strengths.

*Figure 3.55. The point load testing method.*

The compressive strength formula recommended by ISRM was:

\[ \sigma = \left(0.89 \times \frac{F_p}{d^2} \right) \]

\[ d = \text{Thickness of the sample (mm)} \]

\[ F_p = \text{Applied load (N) / Correction factor = 10 was found.} \]

*Table 3.4. The average results of point load test*

<table>
<thead>
<tr>
<th>Mortar Samples</th>
<th>Compressive Strength (MPa)</th>
<th>Uniaxial Compressive Strength (MPa) (with correction)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th Century</td>
<td>0.4*</td>
<td>4*</td>
</tr>
<tr>
<td>Medieval</td>
<td>0.5*</td>
<td>5*</td>
</tr>
<tr>
<td>15th Century</td>
<td>0.6*</td>
<td>6*</td>
</tr>
<tr>
<td><strong>Repair</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th Century</td>
<td>0.6*</td>
<td>6*</td>
</tr>
<tr>
<td>Medieval</td>
<td>0.6*</td>
<td>6*</td>
</tr>
<tr>
<td>15th Century</td>
<td>0.7*</td>
<td>7*</td>
</tr>
</tbody>
</table>