3D Laser Scanner and Reflectorless Total Station: A Comparative Study of the Slots of El-Khazneh at Petra in Jordan

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ABSTRACT

Today, the laser scanners are widely used in the field of architectural, archaeological and environmental surveying because of their practicality and flexibility. A laser scanning machine can be considered as a high automation reflectorless total station; by means of a laser based measurement of distance and accurate angular movement, a target object is sampled in a regular mesh of 3D points. To achieve a real comparison between the technical qualities of the laser scanning machine and reflectorless total station, the case of a high slots and in a vertical position, had been chosen at El-Khazneh (the treasury) at Petra in Jordan, where the use of traditional measuring methods, if not impossible, at least are very difficult to achieve. These slots are located in an inaccessible place beside El-Khazneh, on both the right and the left side. Until now there are no satisfactory measurements of those slots. There are two rows of approximately square holes. The problem of how to choose the viewpoint positions and the time represents important factors of the survey for those slots where the mountainous environment surrounding El-Khazneh restricts potential sensor stations. To overcome this problem and to achieve precise measurements of those slots, we used a 3D laser scanner (Mensi GS 100) to build a 3D mesh model, and a modern reflector-less total station (Leica), which has the ability to use a visible laser beam. The two techniques, the problems and difficulties that arose during the survey process are shown in the paper. The obtained result of these two techniques will be discussed and evaluated.

1. INTRODUCTION

A surveyor collecting data using pre-electronic techniques could have used the tape to take the measurements, together with a cross section for elevation information and quantity estimates, or the survey could have been completed using such polar techniques as transit or theodolite / EDM surveys. In fact, cultural heritage documentation frequently requires integrating survey data from different sources. Currently, the preferred way to achieve this goal is through an integrated use of different documentation technologies. Actually, partitioning processes and integration of different measurement and modeling techniques appear to be useful in cultural heritage documentation and representation. As a general rule, the greater the accuracy required the more time and money will be required to achieve it.

However, a laser scanning machine can be considered as a high automation reflectorless total station; by means of a laser based measurement of distance and accurate angular movement, a target object is sampled in a regular mesh of 3D points. Meanwhile the objects that can be documented range from the sizes of coins or potsherds to whole cultural landscapes. To achieve a real comparison between the technical qualities of the laser scanning machine and reflectorless total station, the case of a high slots and in a vertical position, had been chosen at El-Khazneh (the treasury) at Petra in Jordan, where the use of traditional measuring methods, if not impossible, at least are very difficult to achieve.

2. EL-KHAZNEH OF PETRA AND THE SLOTS

The architecture of Petra reflects the spirit of the Hellenistic and Roman period, where architects moved among different cultures to create high artistic standards in architecture in cooperation with the local tradition in order to achieve a new approach to the stylistic aspect. Thus, the façades are conceived as an independent screen set in the front of the building rather than organic and logical elements of the structure as a whole. What we see in Petra are some of the best preserved samples of late Hellenistic morphology often in an appealing combination of oriental and western stylistic elements.

In Petra, traces of slots can be seen in all of the primary quarries. However, slots can be seen clearly only beside one rock-cut monument; El-Khazneh (The treasury) **Fig 1.** These slots are located in an inaccessible place beside El-Khazneh, on both the right and the left side. Until now there are no satisfactory measurements of those slots. On the recessed walls on each side of the façade there are two vertical rows of approximately square holes **Fig 2**. According to the available measurements as reported in literature, the slots start at 10 m above the floor, and reach only as far as the eagle acroterion of the upper order, **Fig 1**.The distance between the adjacent rows varies from 30 to 45 cm. The height and width of the slots range from 25 to 30 cm. The vertical distance from the base of one step to that of the next is approximately 55 cm. A vertical section through one slot shows that it has a greater depth at the bottom, c.10 cm, than at the top, zero, **Fig 3**. This rock-cut monument is the only one to have such cuttings in Petra.

According to our measurements, the slots start at 12 m above the floor, while the height of the slots range from 15 to 40 cm and the width from 15 to 35 cm in the right side. On the left side the height also range from15 to 40 cm and the width from 20 to 40. However, the slot depth at the bottom range from 8 to 20 cm at the left side, while on the right side they range from 9 to 14 cm and at the top is zero as shown in **Fig 3.**

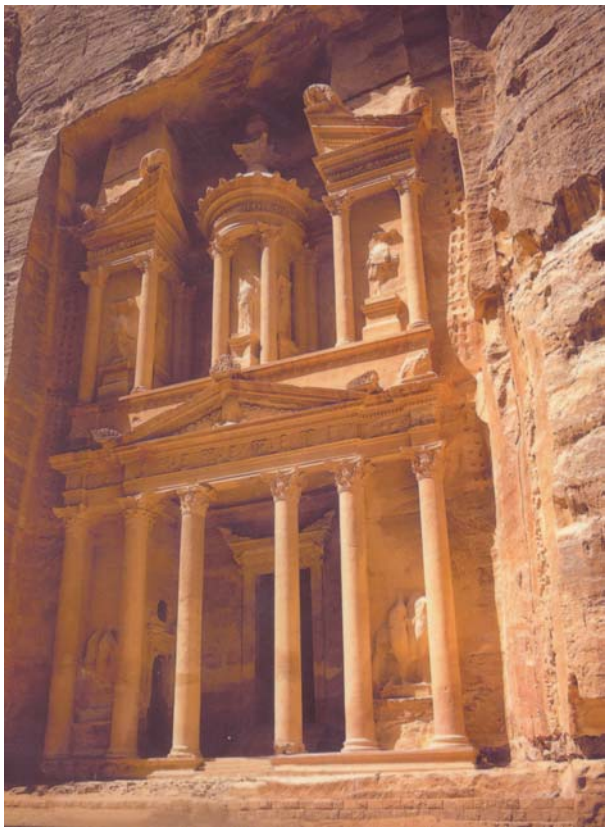


Fig 1. El-Khazneh and the slots beside the rock-cut monument.

On the left side, the horizontal distance between two slots ranges from 20 to 30 cm, while the vertical distance ranges from 15 to 35 cm. Meanwhile, the horizontal distance between two slots on the right side range from 20 to 35 cm, while the vertical distance ranges from 15 to 40 cm.

The question as to what was the function of the tow rows of the slots beside el-Khazneh has not been answered satisfactorily mainly because of their absence in other rock-cut monuments in Petra. However, the Nabataean masons cut their monuments from the top to down. Peter Parr suggested that these were footholds carved and used by the iconoclasts to deface the images of the statues at the building, and not by the original masons. The statues (animal and human images) are located in each outer bay of the lower order, and between each of the front and back supports on the upper order, **Fig 1**.

Meanwhile, Rababeh believe that, the idea that these slots were used for scaffolding to any extent is incredible, for several reasons; the slots do not form a vertical line, instead the lines appear curved, and no two holes coincide horizontally, **Fig 2.** However, to the Nabataeans it would have been time consuming, cumbersome and expensive to erect scaffolding, especially with the huge number of Petra monuments (approximately more than eight hundred). Rababeh conclude that, it is improbable that the slots which appear on the façade of El-Khazneh could have been used to hold wooden beams for constructing scaffolding. Thus, this leads him to suggest the rock-cut horizontal working platforms as the only practical and economical

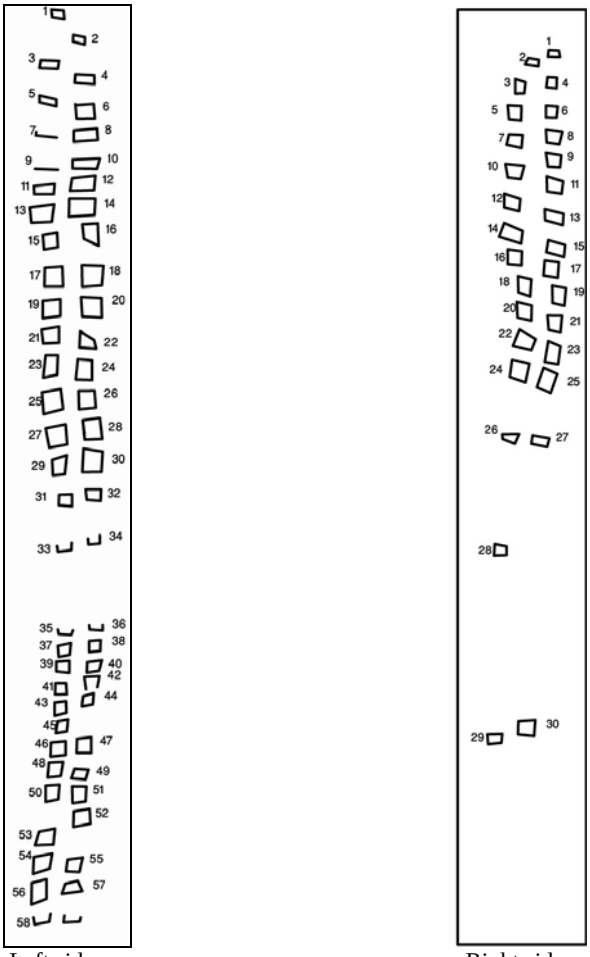


Fig 2. Documentation of the left and the right side of the two vertical rows of the slots beside the El-Khazneh.

solution in carving the different stages of el- Khazneh, and it is more likely that they used the adjacent hillside to reach the monument during the period of the work. Rababeh assume that this arrangement is similar for foothold mountaineers.

However, as they were not used for scaffolding, the question of the use and the function of these slots remains unanswered, while we observe from our measurements that there is a variety and differences in there dimensions; in the height and the width is more than 20 cm, in their depth is between 6 to 12 cm, while in the vertical distance between two slots which ranges between 15 to 40 cm **, Table 1,2,3,4**.

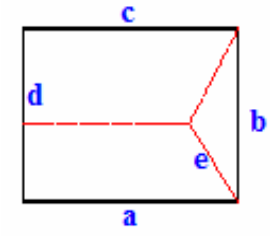


Fig 3 A 3D sketch of a slot showing the length, the width and the depth.

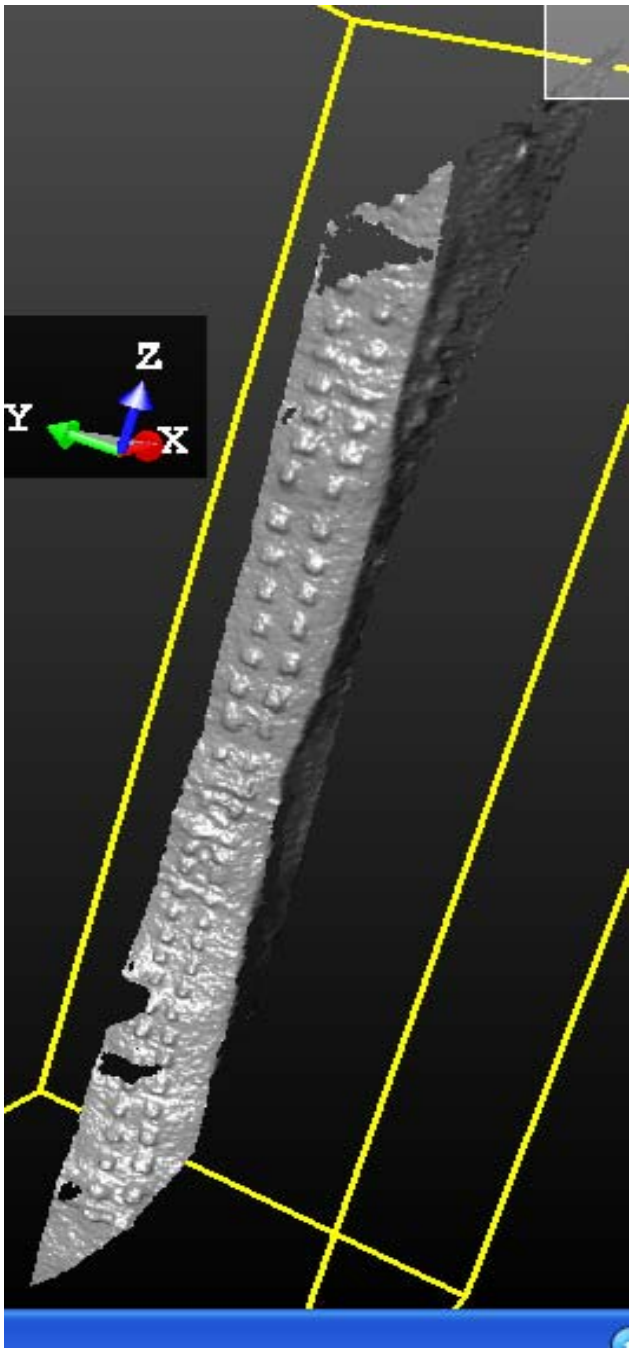


Fig 4 Mesh of 3D points of the whole left side slots back of El-khazneh

measurement recorded using 3D Laser scanner					
Slot ID	a	b	c	d	e
1	230	170	225	195	90
2	-	-	-	-	-
3	310	200	317	210	82
4	350	330	380	290	150
5	300	430	400	470	-
6	240	360	280	350	150
7	350	320	340	400	-
8	380	250	390	280	180
9	420	390	416	400	-
10	440	200	450	150	-
11	380	225	360	220	125
12	410	340	420	300	153
13	360	360	427	328	170
14	430	329	430	387	176
15	254	270	249	282	-
16	290	460	280	330	-
17	290	400	280	400	-
18	332	389	370	426	-
19	312	310	320	373	-
20	351	378	350	380	-
21	260	350	280	349	-
22	280	152	384	380	200
23	250	158	310	390	160
24	-	-	-	-	-
25	400	408	380	420	190
26	230	320	230	318	150
27	310	380	327	400	170
28	270	409	300	401	140
29	200	354	262	307	82
30	321	397	326	449	189
31	260	270	255	274	-
32	230	245	246	268	-
33	250	142	243	109	100
34	198	176	205	110	103
35	250	350	248	330	180
36	280	340	270	328	150
37	200	250	226	237	115
38	137	271	200	265	137
39	220	264	224	276	150
40	210	228	250	221	127
41	200	256	200	270	130
42	197	270	265	310	150
43	205	302	205	294	146
44	200	240	203	250	100
45	202	267	190	270	160
46	267	310	260	305	106
47	270	346	259	340	100
48	255	316	264	310	110
49	250	210	270	240	100
50	240	321	264	375	121
51	219	335	247	390	108
52	319	346	300	346	150
53	320	337	305	324	105
54	326	351	340	402	150
55	290	330	210	350	-
56	320	455	264	478	150
57	400	310	237	263	100
58	280	270	330	270	105
59	300	290	390	330	-

Table 1 Measurement recorded using 3D Laser scanner of the left side slots of the El-Khazneh.

3. THE DOCUMENTATION PROCESS: PROBLEMS AND DIFFICULTIES

Due to mountainous environment surrounding El-Khazneh which restricts potential sensor stations and of the huge number of visitors and tourists, there were some difficulties that arose during the documentation process to choose the viewpoint positions for the survey of the treasury including the slots. To achieve precise measurements of these slots, we used a 3D laser scanner (Mensi GS 100) to build a 3D mesh model, and a modern reflector-less total station (Leica). Though, the difficulty starts from when and how to choose the viewpoint positions for the survey where the environment surrounding restricts potential sensor stations.

3.1 Field work: -

A special attention was paid to choose the time of measurements. All the measurements were conducted either early morning or afternoon before sunset, because particularly during these hours the El- Khazneh lays in soft shade. For the 3D Laser scanner it was essential to perform the recording process in these conditions, because scanning without strong shadows always gives better results and images. The best time for performing the building façade survey was little before the sunset, where it was possible to trace the red laser spot clearly and to get it exactly where it is needed. Three stations were carefully chosen for the 3D Laser scanner, one in the front of the façade **Fig 5**, the second at the right, **Fig 6,** and the third on the left side of the façade, **Fig 7**. The slots on the right and left side of the façade were measured precisely using the reflector less total station, **Table 2, 3.**

3.1.1 Measuring process using 3Dlaser scanner:-

The three stations were carefully located to insure a good cover of the khazneh from different angles and a good overlap between the different stations. The scanner was first sat up over the chosen station, 45 m in front of the el-Khazneh and the whole façade was scanned from this station, **Fig 5**. Then we moved the scanner to the next station on the left side and scanned the façade from a distance of 70 m. Finally we moved the scanner to the top right side of the façade to perform the last stage of the façade scanning (65 m). The acquisition time for each station was varied depending on the number of scanned points and the scanning settings. In general it took us about half an hour of scanning for each station. Meanwhile, it was needed one working day to measure only the slots (500 points) by the reflector-less total station.

3.1.2 Reflector less total station measuring process

From one station, 47 m in front of the El-Khazneh were able to get the all needed measurements of the left and the right side slots. Reflector less mode was used to record most of inaccessible points. The measuring was taken place afternoon and before the sunset to insure that we can trace clearly the laser red spot. However, electronic data collection with reflector less total station instruments permits the quick acquisition of large amount of field data, together with the efficient and error-free transfer of the data to a computer. Once in the computer, the field data can be edited and analyzed for completeness of coverage and accuracy.

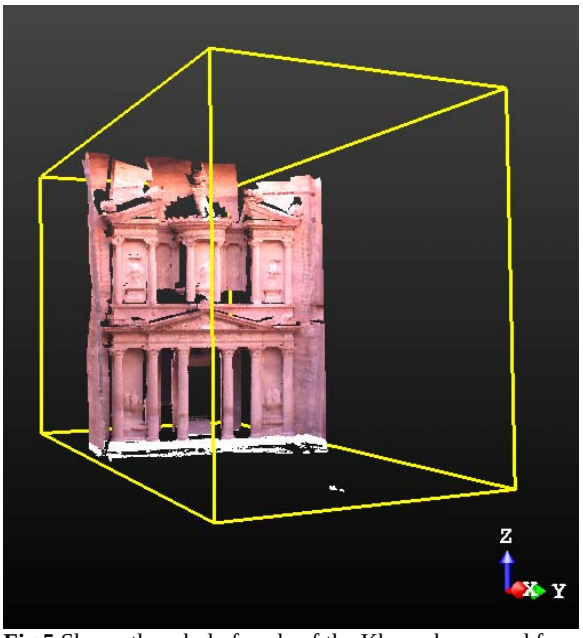
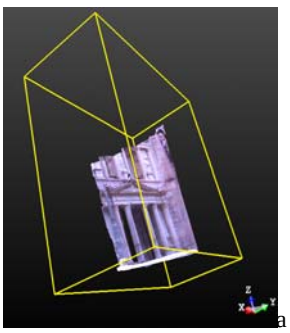


Fig 5 Shows the whole façade of the Khazneh scanned from front (station 1).

3.2 Office work:-

The field Data that had been recorded by the 3D Lasers canner and the reflector less total station were downloaded to the computer for further analysis.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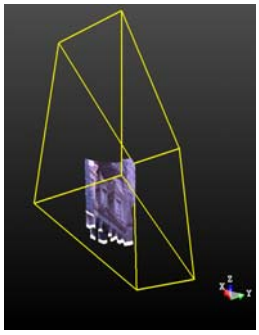
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Fig.6 The lower part of the Khazneh (a) and the upper part (b) scanned from the left station.

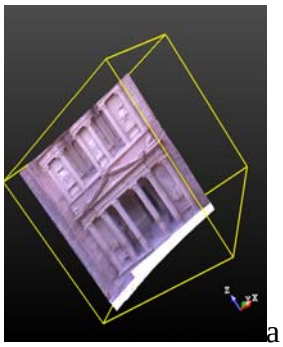
3.2.1 3D Laser scanner field Data:-

A sophisticated software “Real Works Survey” was used to analyze the 3Dlaser scanner’s field collected Data. At the front station 1,282757 points were recorded, while at the right station more than 1,600000 points, and at the left station more than 1,900000 points were recorded. The processing time at the lab, for the whole facade including the slots, was less than one week. Due the difficulty to fix targets or spheres on the façade we weren’t able to perform an automatic mode of registration. Though, we used the so called “cloud-based registration tool” to merge the three stations. Due also to the huge number of the merged points we reduced this number to 19%, without affecting the final shape of the El-Khazneh and the slots. A 3D mesh was built using the merged points . The 3D mesh was used to perform all the dimensional measurements of the slots, **Fig 4.** The mesh was then exported as DXF file. In AutoCAD we were able to manipulate the mesh and to get a nice rendered 3D model of the El-Khazneh including the slots. However, we were able to measure some dimensions of some slots that

were difficult to achieve by the reflector less total station. The dimensions of the left and right side of measured slots are shown in **Table 1, 4**. The related numbers of the slots from 1 to 59 of the left side and from 1 to 30 of the right side are shown in **Fig 2**.

3.2.2 Reflector less total station Data:-

To deal with field data collected by total station, special software LISCAD was used to computation, drawing and analyzing the Data. Though, after downloading the field Data the LISCAD software were used to export the 3D points as DXF file. Meanwhile, in AutoCAD we viewed the 3D points in Isometric mode, in order to see the slots vertically through the façade of the El-Khazneh. All the dimensional measurements were done in this mode, **Table 2, 3**. However, we were also able to measure some dimensions of some slots that were difficult to achieve by the 3D scanner. The dimensions of the left and right side of measured slot are shown in **Table 2, 3**.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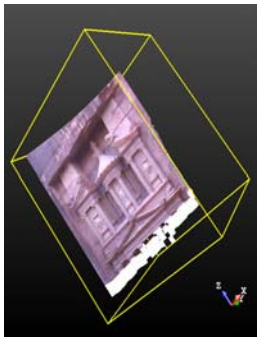
b

Fig.8 The lower part of the Khazneh (a) and the upper part (b) scanned from the right station.

measurement recorded using reflectorless Total station					
Slot ID	a	b	c	d	e
1	215	163	215	171	90
2	213		-		46
3	319	204	319	204	73
4	340	-	-	-	77
5	299	-	-	-	-
6	318	-	-	292	128
7	364	-	-	81	
8	419	250	405	196	187
9	399	-	-	-	-
10	425	235	476	172	-
11	340	220	363	191	134
12	417	331	406	316	161
13	370	373	439	331	174
14	447	341	458	390	181
15	247	293	256	293	158
16	285	452	269	368	184
17	327	394	308	382	195
18	341	393	378	441	191
19	307	333	311	360	190
20	341	383	360	401	169
21	276	331	314	334	201
22	291	160	379	361	190
23	255	401	218	438	146
24	286	401	252	413	122
25	355	396	336	427	194
26	291	334	279	372	151
27	323	403	362	406	207
28	304	416	301	402	122
29	208	360	271	312	75
30	333	404	338	457	198
31	241	281	235	265	66
32	241	250	274	265	37
33	247	150	-	120	113
34	203	180	-	120	99
35	219	95	-	86	120
36	228	120	-	112	114
37	197	261	232	240	100
38	145	273	203	273	145
39	228	270	230	283	157
40	217	235	258	230	120
41	209	262	191	272	137
42	206	277	271	316	163
43	216	297	200	301	156
44	197	251	197	253	105
45	194	272	189	273	162
46	274	300	265	300	117
47	255	350	252	344	83
48	243	324	257	321	122
49	255	216	260	238	96
50	238	331	272	382	128
51	228	341	255	403	112
52	302	331	280	351	166
53	330	351	291	319	117
54	315	344	346	393	148
55	236	314	273	309	102
56	295	475	273	491	148
57	361	288	229	272	102
58	264	163	-	143	114
59	283	91	-	134	55

Table 2 Measurement recorded using reflectorless Total station of the left side slots of the El-Khazneh.

measurement recorded using reflectorless Total station					
Slot ID	a	b	c	d	e
1	222	142	186	151	-
2	243	140	193	151	-
3	163	251	194	320	121
4	186	231	172	222	94
5	225	352	250	354	113
6	195	272	214	291	78
7	279	291	257	244	114
8	230	307	302	300	-
9	230	270	283	312	134

10	267	307	360	313	-
11	283	255	316	322	111
12	276	291	315	320	123
13	357	271	363	294	110
14	420	272	363	323	95
15	351	253	323	282	-
16	267	310	269	330	122
17	268	361	275	341	118
18	247	371	260	370	73
19	224	401	259	390	99
20	264	331	291	341	110
21	228	381	284	321	141
22	349	262	344	409	117
23	261	412	240	495	143
24	307	416	331	383	107
25	280	446	276	456	112
26	241	216	365	100	-
27	292	195	328	159	107
28	230	200	216	260	122
29	242	191	275	189	-
30	294	371	324	290	-

Table 3 Measurement recorded using reflectorless Total station of the right side slots of the El-Khazneh.

	measurement recorded using 3D Laser scanner				
Slot ID	a	b	c	d	e
1	200	120	180	125	90
2	240	120	230	140	-
3	180	220	190	297	-
4	170	225	164	220	90
5	230	332	240	328	120
6	210	265	210	282	85
7	260	290	267	254	120
8	250	293	300	290	100
9	237	260	277	302	110
10	280	294	350	298	118
11	300	242	320	212	110
12	260	280	310	300	-
13	340	266	330	287	140
14	413	257	359	319	90
15	345	243	315	278	80
16	257	298	270	325	130
17	256	370	301	337	95
18	277	363	272	364	90
19	220	394	247	382	100
20	271	340	285	334	90
21	220	375	275	316	-
22	350	260	340	400	80
23	273	402	247	490	120
24	330	420	370	369	140
25	300	440	291	449	90
26	235	220	370	110	90
27	290	295	318	166	-
28	230	200	230	260	95
29	240	180	267	196	-
30	290	363	302	281	-

Table 4 Measurement recorded using 3D Laser scanner of the right side slots of the El-Khazneh.

4. CONCLUDING REMARKS

A comparative measurement study using 3D laser scanner and reflector-less total station of the slots of El-khazneh at Petra in Jordan was conducted. In order to achieve precise measurements of these slots, we used a 3D laser scanner (Mensi GS 100) to build a 3D mesh model, and a modern reflector-less total station (Leica). Actually, we can conclude that from the 3D mesh model of the 3D scanner we were able to measure with the same needed accuracy conducted by the reflector-less total station. The difference in measurements is between 0.2 to 2 cm. **Table 1,2,3,4**.

The fast and economic way of creating a DDSM is one of the most interesting applications of the 3D scanner in comparison with the total stations. Modern technology of the 3D laser scanning, permits measuring and recording with such precision that we must now choose the level of precision that is appropriate or necessary for any project, knowing that the limits are no longer restrictive. However, Laser scanning instruments, are suitable for cultural heritage recording where the use of traditional measuring methods, if not impossible, at least are very difficult to achieve.

To achieve a real comparison between the technical qualities of the laser scanning machine and reflectorless total station the time in the field consist a major factor in this comparison. One working day was needed to measure only the slots by the reflector-less total station, while 1.5 hours was needed for scanning all the façade including the slots. Furthermore, Laser scanning accuracy cannot reach the accuracy of geodetic instruments and can not provide the possibility to increase accuracy through larger image scales. While there is no improvement in the accuracy using laser scanned data, mainly because of the large number of overlapping photos which should be taken, there is a significant gain in labor associated tasks. In addition, the combinations of two recording methods with these detailed measurements of those slots open a new dimension to answer the question of the use and the function of the El-khazneh slots.

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