Using of Laser Scanning Technique to Culture Heritage: The Sample of Kizkalesi

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Key words: Kızkalesi, Laser Scanning

SUMMARY:

This work was done in Mersin's county Erdemli Kızkalesi town. Turkey has done the honours for many civilization because of its location from past to present. Fort his reason traces of every civilization come to until today. These traces are cultural properties which have commended to us from history. Saving these properties and transfer to future generations is one of our cultural duties. In time these works incur big losses because of natural and humane reasons. To being preservable, firstly these terrains have to be documented. Technologic devices have to be used to document them as soon as possible. In this work, the dimensional model of Kızkalesi has been done by using topographic laser scanning techniques.

Check points were measured with Total Station, to prepare Relievo Project and to create 3 dimensional point datas. Laser scanning operation was done with the device Trimble GX3D and point cloud.

ÖZET:

Bu çalışma Mersin İli Erdemli ilçesi Kızkalesi beldesinde yapılmıştır. Türkiye bulunduğu konum itibariyle geçmişten günümüze bir çok medeniyetlere ev sahipliği yapmıştır. Bu sebepten dolayı her medeniyetin izleri günümüze kadar ulaşmıştır.Bu izler bizlere tarihin emanet ettiği kültürel varlıklardır.Bu varlıkları korumak ve gelecek nesillere aktarmak bizlerin kültürel görevlerimizden bir tanesidir.Bu eserler zamanla doğal ve insani sebeplerden dolayı büyük zarara uğramaktadır.Bunların korunabilmesi için öncelikle bu yerlerin belgelenmesi gerekmektedir. Belgelemenin en kısa sürede yapılabilmesi için teknolojik aletlerin kullanılması gerekmektedir. Bu çalışmada, kızkalesinin yersel lazer tarayıcı teknikleri kullanılarak 3 boyutlu modeli çıkarılmıştır.

Röleve projesi hazırlanması için ve 3 boyutlu nokta verilerinin oluşturulması amacıyla Total Station ile kontrol noktaları ölçülmüştür. Lazer tarama işlemi Trimble GX 3D aletiyle yapılmış ve nokta bulutu elde edilmiştir.

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1. INTRODUCTION

Kızkalesi is the most popular holiday centre in Mersin. These castle is in the sea and 500m far away from land. Kızkalesi has 36º 27" 24.47" North, 34º 08" 54.1 East coordinates.

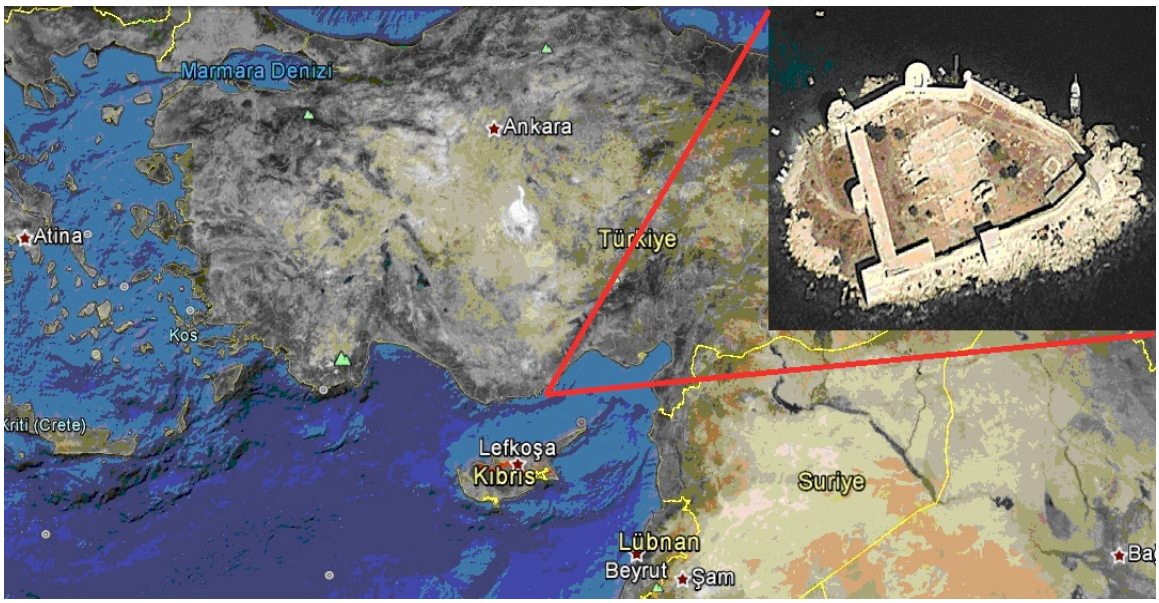

Image1: Location of Kızkalesi

Kızkalesi is guarded with eight towers. The external peripheral length of castle is 192 meter. Kızkalesi, which is important tourism centre of Erdemli, is 23 km far away from Erdemli and 60 km far away from Mersin. Cultural properties requires developed measuring tool and technique to measure in detail and documented because of having different natural features, dimensions and complicated construction. In recent years, topographic laser scanning technique has come to as a standard tool in documenting works of cultural heritage and historical structures in terms of acquiring 3 dimensional data and modeling. This technique gives the opportunity to obtain millions of 3 dimensional point datas, so it gives opportunity to get surface geometries of cultural properties effectively and densely [1]. Point cloud datas, which is obtained from laser scanning, provide datas which will be base for not only 3 dimensional modeling of the structure but also frontal, plan and tomography that is essential for plans of building survey. If any cultural objects are damaged or demolished any of reasons, measuring, plan and sectioning operation are called as the building survey which provides reconstruction down to the last detail of the structure [6].

2. TOPOGRAPHIC LASER SCANNING TECHNOLOGY

It is a technology which provides to get 3 dimensional coordinations of objects directly, delicately and automaticly [5]. It has an application area in registration procedures of cultural heritage and especially in the engineering projects[4]. This technology can be used in the work of cultural heritage and archeological areas for different purposes to form 3 dimensional models with high precision, to have high incidence of detail about the object and coupling[3].

In the works of documentation, cultural properties to scan small sculptures, objects, close-range scannings, which work with the method of triangulation, are used. The scannings which is used with phase comparing method and with stream-arrival time of laser beam, is used in the works of documenting of historical building, archeological areas and big areas[7].

3. STUDY AREA

The castle formed on a small holm that is 500m far away from coast, is called Kızkalesi. **(Image 3)**. It is guarded with eight towers. The external peripheral length of the castle is 192 meter. Kızkalesi, which is important tourism centre of Erdemli, is 23 km far away from

Image 3: Interior and external apperance of Kızkalesi

Erdemli and 60 km far away from Mersin.

This work forms 2 phases that they are the works of terrain and bureau. Our terrain working was formed with preparation before work, coordinatement of check points with total station and attachment them, and field scanning with laser scanning tool.

3.1.Preparation Before Work

Laser scanning tool and electronic Total Station **(Image 4 and Image 5),** paperboards, which is pasted to walls, were provided for modeling of Kızkalesi **(Şekil 6).**

Device Type	Long range Laser Scanning System
User Interface	PC,WindowsNT/2000
Ideal usage range	2-100 m
Maximum Scanning Rate	5000 point/second
Standard Deviation	6.5mm in 200m
Scan Resolution	3mm in 50 metric distance
Distance Measuring Method	Time of Flight
Camera Zoom Factor	Up to 5.5x
Accuracy in Modelled Surface	+-2mm
Accuracy of Single-point	7 mm in 100m
Point of view; Continuous monadic scanning	360ºx60º
Dot pitch	Under 3.2 mm in 100

Image 4: Laser Scanning (Trimble GX 3D) used in work

Distance Measuring Operation 200m without reflector

- It provides high data recording area with 10.000 points internal memory capacity
- Measurement precision +-2mm +2ppm
- Reading aspect 2cc

Image 5: Total Station used in work (Geomax ZTS 605)

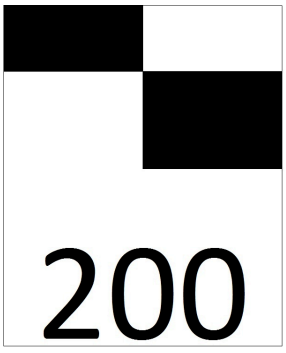

Image 6: Paper target sign in A4 size

Image 7: Attachment of paper targets to wall (Ulvi A. ,2012)

3.1.1. Measuring of Check Points in the Working Area

Aspect and distance measures: Vertical angle, horizontal angle, slant range was measured with Total Station Geomax ZTS 605 device which measures without reflector laser **(Image 5).** After fixed the device and levelled, device was reset to bottom of reflector, which is holded to benchmark, by directing binoculars of device. It was done an observation to other polygon point without moving the device horizontally, only by fixing binoculars to reflector, by measuring distance and aspects to check.

3.1.2. Modeling by Using Point Clouds With Topographic Laser Scanning

Documentation working used in laser scanning method, was carried out at 4 operation phases. These operation phases are planning before scanning, scanning, data processing and evaluation. **(Image 8)**

Planning Before Scanning	Defined of station positions and numbers
Scanning Operation	- Placement of Targets - Scanning of general area

Processing of Datas	- Computerized of Datas - Forming 3 dimensional point clouds of structure
Evaluation	Planning and transecting of the structure from 3 dimensional point cloud

Image 8: Phase of Topographic Laser Scanning Operation

Scanning operation has be planned before doing scanning in the terrain. In the phase of planning, positions and numbers of stations have to be defined. To be scanned stations' positions have to be defined in sufficent number by involving the whole structure and all details. While defining positions of these stations, unscanned areas by keeping them in a bakground in a station have to be defined from other stations to scan them and it has to be made a point of setting out in full. In the phase of scanning operation plan, with which coordinate system it will be combined with point cloud have to be defined. This reference system could be a geodesic coordinate system or a scanner based local coordinate system. If the reference system of scanning is a geodesic coordinate system, coordinates of target points used as linkup have to be defined according to this coordinate system.**(Image 9 and Image 10)**

Image 9: Topographic Laser Scanning Operation (Ulvi A. ,2012)

Image 10: Topographic Laser Scanning Operation (Ulvi A. ,2012)

Scan resolution was done with 1,5 cm space in this work.

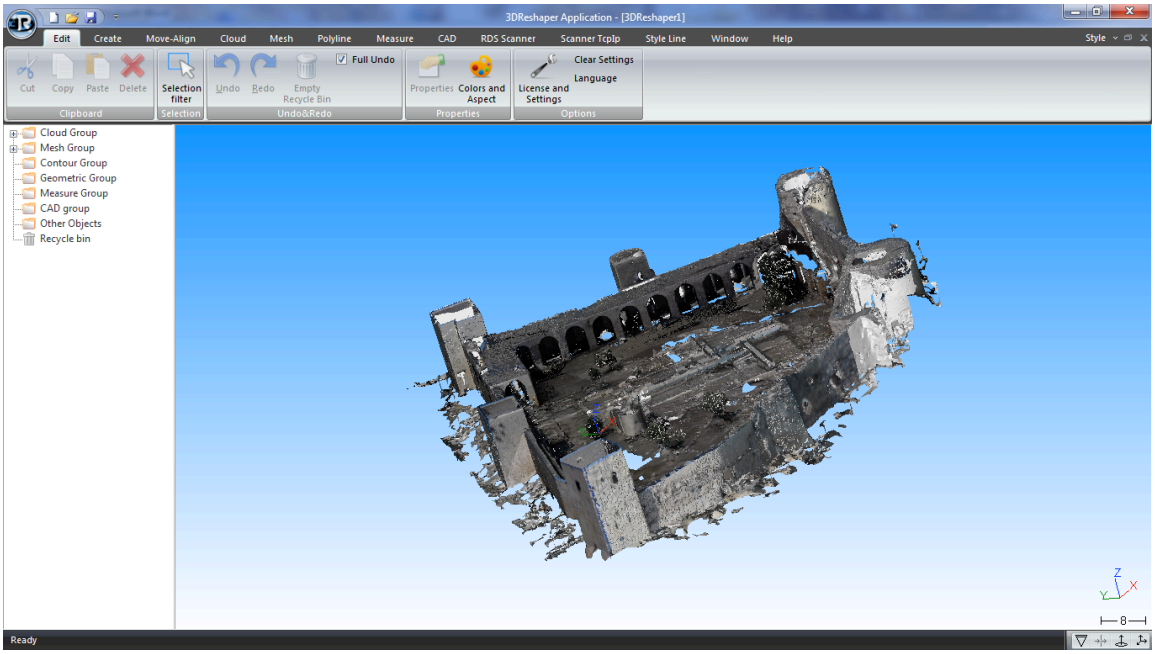

Image 11: General appearance of Kızkalesi

4. RESULTS OF SCANNING

Laser scanning was done with **Trimble GX 3D** laser scanning from 25 different station and with 1,5 cm space **(Şekil 12).** Every scanning was done at least 4 linkups in mutual areas.

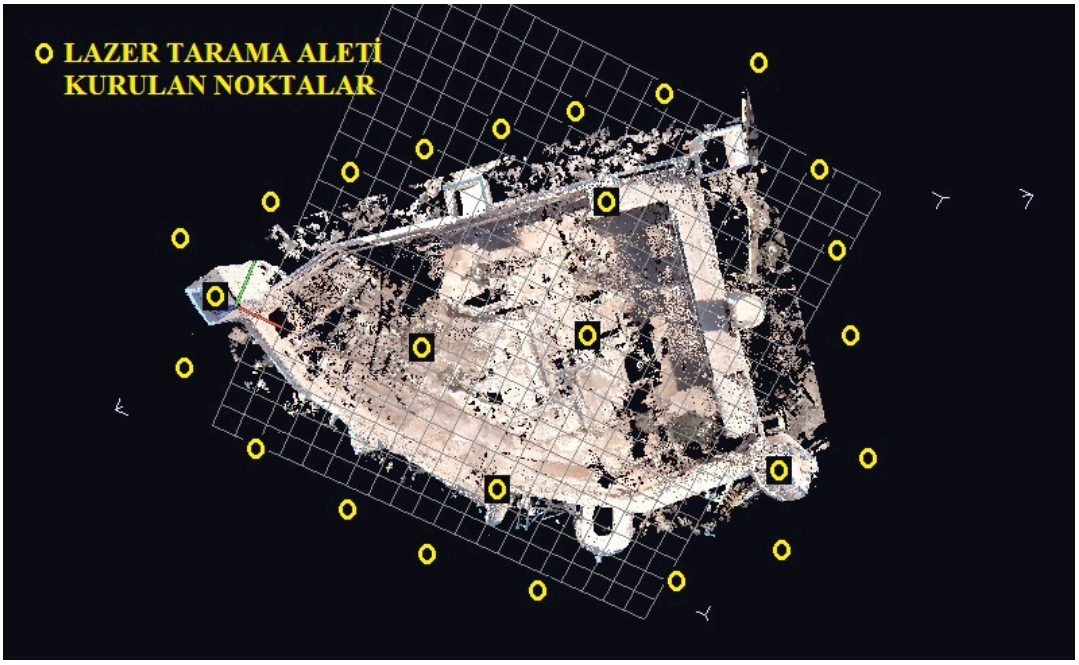

Image 12: Scanned Stations of laser scanning Trimble GX 3D

Coordinates of points (**30.374.829 adet**) obtained from scanning, were transformed general coordination system. Coordinates obtained from Total Station , and gained apparent 30 points is given in Graph 1.

	Total Station (Local)			Manüel Combination (Scanner)		
N.N	x	y	z	x	y	z
200	1062.869	1001.8	106.452	1062.852	1001.81	106.461
201	1066.371	990.579	106.926	1066.356	990.592	106.917
204	1057.593	1019.234	103.36	1057.605	1019.225	103.368
205	1054.075	1028.673	103.419	1054.065	1028.677	103.424
207	1041.188	1044.834	103.061	1041.199	1044.832	103.046
215	978.213	1076.558	103.887	978.22	1076.563	103.873
210	1036.657	1055.185	102.957	1036.669	1055.19	102.965
227	976.975	1071.362	102.642	976.98	1071.377	102.656
231	993.271	1006.046	97.445	993.282	1006.036	97.458
233	1000.696	979.175	103.245	1000.678	979.17	103.257
244	1033.941	996.184	96.047	1033.95	996.18	96.052
246	1059.401	1000.627	100.78	1059.407	1000.632	100.763
251	1041.983	1042.934	97.55	1041.992	1042.949	97.541
254	1019.25	1063.525	95.603	1019.262	1063.512	95.619
256	990.776	1074.938	96.083	990.761	1074.948	96.093
316	998.873	973.44	99.774	998.858	973.452	99.765
320	1033.904	983.151	94.607	1033.916	983.142	94.615
322	1047.489	992.073	95.013	1047.48	992.078	95.016
325	1065.944	1001.945	93.436	1065.954	1001.943	93.421
330	1053.376	1039.015	95.83	1053.383	1039.02	95.817
343	976.738	1079.785	96.669	976.75	1079.79	96.679
350	979.804	1040.886	94.338	979.811	1040.901	94.348
357	992.962	1000.645	94.647	992.971	1000.635	94.658
360	997.959	976.37	93.776	997.941	976.365	93.788
363	1005.918	971.492	93.32	1005.926	971.487	93.325
367	1019.654	984.318	95.773	1019.66	984.323	95.758
377	982.252	1033.606	101.016	982.261	1033.622	101.007
383	1002.674	1073.688	102.134	1002.685	1073.674	102.15
387	1037.373	1056.449	102.738	1037.354	1056.444	102.726
394	1053.986	1038.941	103.815	1053.995	1038.936	103.819

Graph 1: Coordinates obtained with Total station and Manual Combination

Coordinates which was defined by Total Station were based, because measuring accuracy of Total Station is better than measuring accuracy of scanning (Total station; 2mm +-2ppm, Scanner: 7 mm in 100m).

N.N	dx(mm)	dy(mm)	dz(mm)
200	17	-10	-9
201	15	-13	9
204	-12	9	-8
205	10	-4	-5
207	-11	2	15
215	-7	-5	14
210	-12	-5	-8
227	-5	-15	-14
231	-11	10	-13
233	18	5	-12
244	-9	4	-5
246	-6	-5	17
251	-9	-15	9
254	-12	13	-16
256	15	-10	-10
316	15	-12	9
320	-12	9	-8
322	9	-5	-3
325	-10	2	15
330	-7	-5	13
343	-12	-5	-10
350	-7	-15	-10
357	-9	10	-11
360	18	5	-12
363	-8	5	-5
367	-6	-5	15
377	9	-16	9
383	-11	14	-16
387	19	5	12
394	-9	5	-4

Graph 2: Difference between coordinates obtained from Laser Scanning and coordinates obtained from Total Station.

Precision criterion was defined for every coordinate combination by benefiting from coordinate differences of characteristic points in Kızkalesi. In this phase, precision criterion was calculated nominally. Average distance between Toatal station and object points= 40 m were chosen and weight for every point= 40/si was defined. (Graph 4)

Graph 3: Correction Values (V=Safe Bill- Measurement Value)

N.N	Vx	Vy	Vz
200	17	-10	-9
201	15	-13	9
204	-12	9	-8
205	10	-4	-5
207	-11	2	15
215	-7	-5	14
210	-12	-5	-8
227	-5	-15	-14
231	-11	10	-13
233	18	5	-12
244	-9	4	-5
246	-6	-5	17
251	-9	-15	9
254	-12	13	-16
256	15	-10	-10
316	15	-12	9
320	-12	9	-8
322	9	-5	-3
325	-10	2	15
330	-7	-5	13
343	-12	-5	-10
350	-7	-15	-10
357	-9	10	-11
360	18	5	-12
363	-8	5	-5
367	-6	-5	15
377	9	-16	9
383	-11	14	-16
387	19	5	12
394	-9	5	-4

Graph 3:Correction Values

N.N	Distance(Si=m)	Weight (So=40 m) Pi=40/Si
200	48.99	0.816
201	42.55	0.94
204	54.33	0.736
205	48.03	0.832
207	34.11	1.172
215	59.83	0.668
210	71.61	0.558
227	54.52	0.733
231	25.14	1.591
233	39.59	0.01
244	35.29	1.133
246	46.15	0.866
251	34.69	1.153
254	52.53	0.761
256	23.95	1.67
316	39.02	1.025
320	22.29	1.794
322	33.23	1.203
325	28.05	1.426
330	45.98	0.869
343	62.87	0.636
350	25.36	1.577
357	27.71	1.443
360	40.9	0.978
363	31.72	1.261
367	28.43	1.406
377	20.04	1.996
383	33.18	1.205
387	71.53	0.559
394	46.59	0.858

Graph 4: Distances and Weights from Total Station to points

Benefit from nominal results, point position alterations were tried to determine 3B position accuracy was calculated like in formula (1) [2].

Ağırlıklı $$Sx_0 = \sqrt{\frac{[PVxVx]}{n-1}} \quad Sy_0 = \sqrt{\frac{[PVxVx]}{n-1}} \quad Sz_0 = \sqrt{\frac{[PVxVx]}{n-1}}$$

3B Konum Doğruluğu $$S_{3B} = \sqrt{Sx_0^2 + Sy_0^2 + Sz_0^2}$$ (1)

Nominal Values	(mm)		
	Sx	Sy	Sz
Standard Deviation	12.058	10.226	11.831

Graph 5: Nominal (different precision) values (mm)

Result of nominal values, calculated position accuracy for every point was calculated Formula (2) and results were given in Graph 5. For every point, 3B position accuracy was obtained from Formula (3) with Standard deviation of nominal measure.

$$Sx_i = \frac{Sx_0}{\sqrt{Pi}} \qquad Sy_i = \frac{Sy_0}{\sqrt{Pi}} \qquad Sz_i = \frac{Sz_0}{\sqrt{Pi}}$$

3B Konum Doğruluğu $$S_{3B_i} = \sqrt{Sx_i^2 + Sy_i^2 + Sz_i^2}$$ **(2,3)**

Nominal Values (mm)				
N.N	Sx(i)	Sy(i)	Sz(i)	3B-Si
200	13.34485	11.31734	13.09336	21.854
201	12.43683	10.54728	12.20245	20.367
204	14.05335	11.9182	13.78851	23.014
205	13.21345	11.20591	12.96444	21.639
207	11.13528	9.443469	10.92542	18.235
215	14.74754	12.50691	14.46961	24.151
210	16.13418	13.68288	15.83012	26.422
227	14.0779	11.93902	13.8126	23.054
231	9.559666	8.107246	9.379508	15.655
233	11.99645	10.17381	11.77037	19.645
244	11.32624	9.605424	11.11279	18.548
246	12.95227	10.98441	12.70818	21.211
251	11.22955	9.523418	11.01792	18.390
254	13.81859	11.7191	13.55817	22.630
256	9.33067	7.913042	9.154827	15.280
316	11.90978	10.1003	11.68533	19.504
320	9.001505	7.633887	8.831865	14.741

322	10.9907	9.320857	10.78357	17.998
325	10.09779	8.563615	9.907494	16.536
330	12.92839	10.96416	12.68475	21.172
343	15.11756	12.82072	14.83266	24.757
350	9.601403	8.142642	9.420458	15.723
357	10.03641	8.511556	9.847266	16.436
360	12.19331	10.34076	11.96352	19.968
363	10.73808	9.106621	10.53571	17.585
367	10.16596	8.621426	9.974378	16.648
377	8.535107	7.23835	8.374256	13.977
383	10.98243	9.313842	10.77545	17.985
387	16.12517	13.67524	15.82128	26.407
394	13.01387	11.03664	12.76861	21.312

Graph 6 : 3B position accuracy (for every point) nominally

Considering coordinate differences and their standard deviations, t-test was applied to coordinate differences obtained from manual method if it is meaningful or not. Calculated test sizes were given in Graph 7. These values were compared with limit value in t-chart and with degree of freedom (f=n-1)and a=0.05 mistake possibility, t-test limit value is 2.05.(for f=30-1=29 degree of freedom and a=0,05 mistaking possibility) When the graph 7 is analyzed, it is seen that all test values are seen under limit value.

	Tx=Vi/Sxi	**Ty=Vi/Syi**	**Tz=Vi/Szi**
200	1.273	-0.883	-0.68737
201	1.206	-1.232	0.737557
204	-0.853	0.755148	-0.58019
205	0.756	-0.35695	-0.38567
207	-0.987	0.211787	1.372945
215	-0.474	-0.39978	0.967545
210	-0.743	-0.36542	-0.50537
227	-0.355	-1.25638	-1.01357
231	-1.150	1.233465	-1.386
233	1.500	0.491458	-1.01951
244	-0.794	0.416431	-0.44993
246	-0.463	-0.45519	1.337721
251	-0.801	-1.57506	0.816851
254	-0.868	1.1093	-1.1801
256	1.607	-1.26374	-1.09232
316	1.259	-1.18808	0.770196
320	-1.333	1.178954	-0.90581

322	0.818	-0.53643	-0.2782
325	-0.990	0.233546	1.514005
330	-0.541	-0.45603	1.024853
343	-0.793	-0.38999	-0.67419
350	-0.729	-1.84215	-1.06152
357	-0.896	1.174873	-1.11706
360	1.476	0.483524	-1.00305
363	-0.745	0.549051	-0.47458
367	-0.590	-0.57995	1.503853
377	1.054	-2.21045	1.074722
383	-1.001	1.503139	-1.48486
387	1.178	0.365624	0.758472
394	-0.691	0.453036	-0.31327

Graph 7: t- test

5.CONCLUSION

As a measurement device, widely used of topographic laser scanning technology have been making progress in recent years. Laser beam used in scanning is used for both length measuring and screening. In our day, iti is very important to have fast and in full 3 dimensional model and visual knowledge with minimum cost. To use 3 dimensional knowledge for different purposes, alot of datas have to be collect fastly. When it is needed to get knowledge fastly about an object, traditional geodesic and numeric photogrammetric methods remain incapable. In this situations, topographic laser scanning method,which allows 3B measurement of object geometry fastly at high accuracy, can be used.

Especially, usage of this method, which begins to have an important place at the engineering field, become widespread gradually, and provides good advantages in terms of time, cost and labour for users.

In this work, the position alterations in characteristic points of Kızkalesi is defined. Points on the surface of this structure are measured with **Geomax ZTS 605** Total station device and coordinates were obtained in general system. As a result of Topographic laser scanning, within oriented point cloud masses, which were obtained from manual combination, were created identical point masses by defning coordinates of same points. Comparison between identical point coordinates defined manual and coordinates defined with Total Station, is done.

Differences between coordinates obtained from Total station and -16mm and 17mm in

manual method was found. Benefit from difference between characteristic points obtained from Total station and Laser scanning, for every coordinate combination, precision criterion is defined. Benefit from results found nominally, alteration of point position is defined. Accuracy of point position is found ± **19,7** mm nominally. For every point, accuracy of position is found between ±**13.9** mm and ± **26.4** mm nominally.

Considering calculation of the coordination differences and standard deviation of them, t—test was applied whether coordinate differences which is obtained from total station and laser scanner, is meaningful or not. When t-test results are analysed, all test values are seen under limit value.

Considering accuracy of measurement given by producing company, coordinate differences defined with manual combination, are seen within limits of accuracy of measurement.

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