E1) Assessment of water supply and drainage systems for an historical hammam by using non-destructive methods

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Abstract

The original water supply and drainage systems of historical baths (hammams) should be well examined in terms of their performances, discharge capacities, adequacies and faults in order to keep their proper functioning for long periods of time. This study was conducted on a 15th century Ottoman bath, the Sengul Hammam, located in the province of Ankara, Turkey. Some non-destructive methods were used in the study. The surface grading of interior floors, roof surfaces and immediate grounds of the building were examined by levelling survey. The mapping the decay forms and infrared imaging of the building surfaces together with the drainage calculations were used to investigate the faults of the waste water collection and discharge system at interiors and the roof drainage system. The capacity of the hot and cold water supply system was examined by taking into account the usable volume of the hot and cold water storage rooms, number of users/clients, amount of water consumption and reserve capacity of the water supply system. The rainwater drainage system was evaluated in terms of its discharge capacity, adequacy and faults. Results showed that the existing conditions of the waste water collection and discharge system and the roof were found to fail due to wrong interventions and lack of maintenance. Some urgent and long-term maintenance programs were suggested to improve the service systems of the building

Keywords

Hot and cold water supply system; rainwater drainage system; waste water collection and discharge system; non-destructive evaluation ; Sengul Hammam

1 Introduction

It is essential to better understand the original water supply and drainage systems of historical baths (hammams) in terms of their performance, capacity and adequacy in order to keep their proper functioning for long periods of time. Therefore, extensive studies are needed to discover those technologies and to define appropriate maintenance/conservation programs for their survival. These studies should preferably be done by using non-destructive methods.

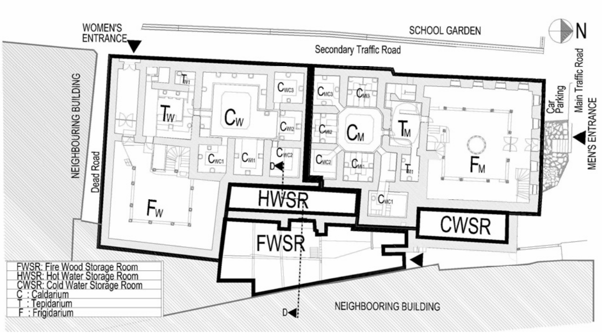
Such a study was conducted on a 15th century Ottoman bath building, the Sengul Hammam[1], located in the province of Ankara, Turkey. This study was focused on the investigation of hot and cold water supply systems, waste water collection and discharge system of the interiors and rainwater drainage systems consisting of roof and surface water drainage of this building. The study consisted of the mapping of decay forms, levelling survey, infrared thermography (IRT), water supply capacity and waste water and rainwater drainage calculations. The contemporary calculations were adapted to the calculations used in this study by taking into account the characteristics of Sengul Hammam.

2 Sengul Hammam

The Sengul Hammam is a typical Ottoman double bath consisting of two separate parts for men and women (Figure 1). It was constructed with stone masonry walls with brick transitions and brick upper structure [1]. The floors of the hammam were covered with marble tiles at interiors.

Figure 1- Views of the Sengul Hammam: the north façade – (a) entrance to the men’s part (at the left); (b) the west façade - entrance to the women’s part (at the right).

Each bath was composed of basically seven sections: Frigidarium (F), Tepidarium (T), Caldarium (C), cold water storage room (CWSR), hot water storage room (HWSR), firewood storage room (FWSR) and furnace (F). These sections both for the women’ and men’s part were presented in Figure 2. The tepidarium and caldarium sections are used for bathing purposes. The body is gradually adapted to heat in tepidarium section before entering the hottest section, the caldarium. Both sections are heated underneath An elevated marble platform, *“göbektaşı”,* was located at the center of the caldarium, which is the hottest surface of the hammam. There are also stone basins (*kurna*) in which hot and cold water were mixed to achieve a desired temperature for bathing. In as-is case, there are 43 basins in total: 24 basins in women’s part and 19 basins in men’s part. The firewood storage and hot and cold water storage rooms are located at the east side of the building (Figure 2). The furnace is located at the bottom of hot water storage room (Figure 3).



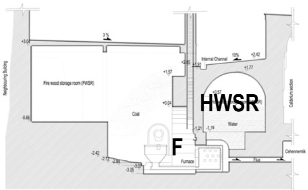


Figure 2 - Plan of Sengul Hammam showing the sections for women's and men's parts and the section DD showing the locations of furnace and hot water storage room

2.1 Hot and cold water supply system

It was told by the operators that the cold water was supplied from the mountain Elmadag, located 41 km at the east of Ankara (Figure 3). The cold water storage room was fed with this water source by means of terracotta piping system in the past and then distributed in the structure with the terracotta pipes buried in the masonry wall in two lines: one is for the cold water and the other one for the hot water supply. The historical water supply system is out of usage at present, however the stoppers the original galvanized steel pipes feeding the taps of stone basins were visible on the wall (Figure 4). A galvanized steel piping system functioning currently runs horizontally over wall and plaster at a level above the level of original piping system hidden in the wall in the range of 0cm - 15cm. The line of historical terracotta pipe was partially visible running in the west wall of the firewood storage room (Figure 5) which was thought to carry cold water from the cold water storage room to the hot water storage room.

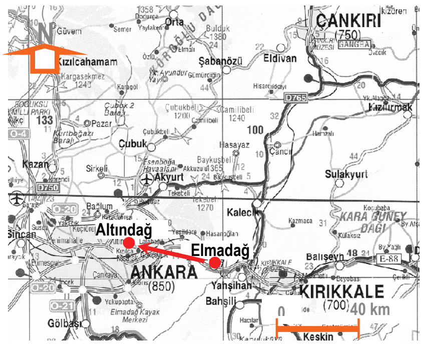


Figure 3 – The cold water source was thought to be carried from the mountain Elmadag which was located 41 km at the east of Ankara.

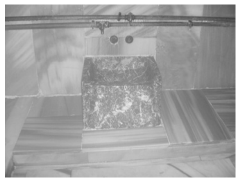


Figure 4 - The location of the stoppers belonging to the original water supply system was observed to be located close to the level of present piping system.

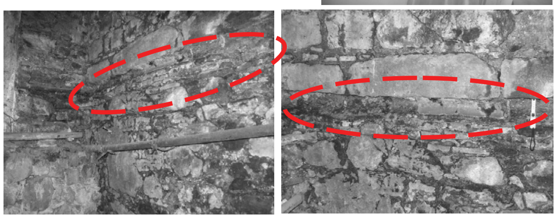


Figure 5 – Views of the original line of terracotta pipe running in the west wall of the firewood storage room.

For the hot water storage room, the interior dimensions in length, width and depth between the overflow and outlet levels were measured to be 14.7m x 3.1m x 1m, respectively and 10m x 3.5m x 1.8m for the cold water storage room. The only source of water is the cold water storage which feeds the hot water storage room as well.

2.2 Waste water collection and discharge system

The discharge components of the waste water collection and discharge system were the open channels and floor drains. Their dimensions were observed to vary in the range of 6cm x 4cm and 14cm x 18 cm in width and depth. A surface slope arrangement in the form of cross falls at both sides of the water channels was also observed to direct the waste water towards the channels and then discharge it from the floor drain located in the toilet. Such surface grading and waster water discharge system was commonly used in the historical hammams [2], [3], [4], however, the existing surfaces of Sengul Hammam was renewed with the recent interventions and the original forms and slopes were disturbed.

2.3 Roof and surface water drainage system

Above the tepidarium and caldarium sections, hot water storage and firewood storage rooms of the hammam, the roof including the dome surfaces was repaired with an addition of 8 cm thick mesh-reinforced concrete layer (Figure 6). The roofs of the frigidarium sections at the north and south are timber pitched roofs covered with fired-clay roof tiles (Figure 7). The immediate periphery of the structure was totally surfaced with asphalt pavement (Figure 1)

Figure 6 - The general view of the mesh-reinforced concrete roof above the caldarium and tepidarium sections (at left)

Figure 7 - The pitched roof, A1, over the frigidarium of women's part with its discharge components: gutter and downpipes (at right).

The roof of Sengul Hammam was mainly composed of four roof areas; A1, A2, B1, B2, having different geometry and drainage systems (Figure 8). The roofs A1 and A2 were the pitched roofs similar with each other. A peripheral drainage system was provided by means of zinc eaves gutters and fourteen downpipes, some of which discharge water directly onto the concrete-clad roof, B1 (Figure 7). The roof B1 was a low-slope roof, configured to provide a peripheral drainage, with flows from elevated interior edges to lower exterior ones, and then, to waterspouts located at the eaves level along the west side of the roof (Figure 1b). There were nine spouts, with similar dimensions, serving this roof area. The water discharged from the roof areas, A1, A2 and B1, were conveyed to the rainwater discharge network of the city by means of surface grading and area drains of the street. The roof B2 was a flat roof configured to provide an internal drainage, with flows towards an internal channel located at the middle of the roof area (Figure 9). The collected water was discharged through a grilled inlet located at the north end of this channel, and then, carried by a drain line (buried in the garden) to the rainwater drainage network (buried under the street).

In as-is case, the flow dimensions of the spout outlets were measured as in the range of 6cm-12cm in width and 6cm-11cm in depth (Table 1). Among all, the original spout

WS6, having flow dimensions of 10cm x 7cm in width and depth, seemed to be the mostly-preserved one (Figure 10). The eaves gutters used for the pitched roofs were measured to have the diameters of 14 cm and 16cm connecting to the downpipes with diameters of 8 cm and 10cm.

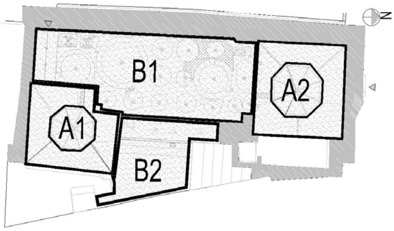


Figure 8 - Plan of the building, showing the roof areas and grounds under study: **A1** – timber pitched roof above the women's frigidarium section; **A2**-timber pitched roof above the men's frigidarium section; **B1**–mesh-reinforced concrete roof above the caldarium and tepidarium sections; **B2**–mesh-reinforced concrete roof above the hot water storage room and the fire wood storage room; **Grey-shaded areas**–immediate grounds under study.

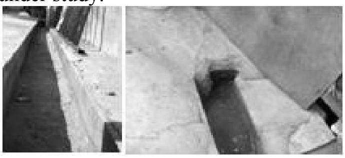


Figure 9 - The interior channel and the drain discharging water from concrete clad flat roof, B2.

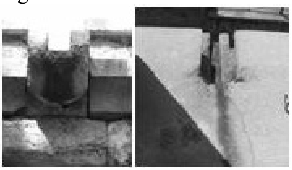


Figure 10. The views of the original water spout, WS6.

3 Methods

The hot and cold water supply systems, waste water collection and discharge system and rainwater drainage system consisting of roof and surface water drainage were examined by non-destructive investigations methods. These methods were the levelling survey, infrared imaging, storage capacity calculations for hot and cold water supply systems and discharge capacity calculations for the waste water and roof drainage systems.

Following a preliminary on-site visual survey to reveal the salient features and the problem areas of the building, a planimetric survey was conducted to record the topographical features of the interior floors, roof and the immediate grounds of the building periphery. Readings were then converted into the detailed maps of the interior floors and the roof, both of which indicating the surface slope arrangement in reference to discharge components, such as waste water collection channels at interiors of hammam or waterspouts of the roof. These maps made it possible to locate the areas having a potential risk of ponding due to the insufficient and/or reverse slopes. The areas under study, were scanned by a thermal camera to detect damp zones. During the analyses of infrared images, a special attention were given to:- (i) the immediate floors of basins at bathing spaces, (ii) the lower parts of the walls at points where a roof drainage component existed overhead, (iii) water leakages of water supply system buried in walls.

The water reserve capacity of the hammam was found out on an assumption that the water heated in the hot water storage room should be consumed in one day. This assumption also corresponds with the contemporary regulations and standards for water storage tanks [5], [6]. The amount of water consumed by one person was also assessed by taking into account the number of users/clients according to the number of original basins.

Roof drainage calculations were made to assess the discharge capacity of the roof discharge components and their adequacy whether they provide acceptable rates of water evacuation from roof surfaces. The method used for the roof drainage calculations was based on the method explained in the literature [7-12] and adapted to the characteristics of the roof at hand.

The results were then interpreted together to examine the water supply, waste water discharge and rainwater drainage characteristics of the hammam in terms of their characteristics, faults and potentials for taking corrective action. The unconscious interventions recently-done were also discussed.

4 Results and Discussion

The results were interpreted in terms of water supply and storage capacity of the hammam, evaluation of the waste water discharge system and the adequacy of the roof and surface water drainage systems.

4.1 Water supply capacity

The usable volumes of the hot and cold water storage rooms were calculated to be 45000 l and 62000 l, respectively. These values were the original water reserve capacities of the hamam since the dimensions of the storage rooms and overflow and outlet levels were not changed in time.

For the calculations of water storage and consumption capacities, some assumptions and acceptances were necessary. The original number of basins was accepted to be 15 in total for the men's part and 23 in total for women's part by taking into consideration the later interventions, such as addition of new basins and/removal of original ones. That means that the existing number of basins, which was 43, was accepted to be 38 in the past. The working period in the past was assumed to be 12 hours while this period is longer today, such as reaching to 18 hours for men's part and 13 hours for women's part. Although the duration of using the hammam could be longer, the occupation period of the basin was assumed to be 2 hours in average for each user. Each basin was thought to be used by only one person although it could be shared by two or more users, such as by mother and child or by two close friend. Considering all, the capacity of the hammam in terms of users was calculated to serve for a total of 228 persons in a day, in the past, in case that the hamam was used continuously. The total amount of hot water consumed by one person in the hammam was calculated to be 200 l/person including all activities of cleaning. To arrange the temperature of water, four units of hot water was assumed to be mixed with one unit of cold water. This meant that the total water consumption for one person was found to be 250 l/per person including all activities of cleaning. In one day, the hammam was found to consume water 57000 l/day. The contemporary standards, such as TS 1258 (1983) and BS6700 (1987) require the cold water storage to cover 24 hours of interruption supply [5],[6]. The usable volume of cold water storage room, 62 000 l, which is slightly higher than the total water consumption of this hammam, was found to satisfy this requirement. This water storage capacity was also found to cope up with the other activities consuming water, such as general/routine cleaning the hamam, washing towels and bathing cloths, toilet cleaning.

In addition, at the firewood storage room, some parts were found to suffer from serious dampness problems due to the water leakages from the hot water storage room and pool at the of the men's part, the room C_{MC1}. In Figure 11, the colder areas shown in the IR images presented the wet areas due to these leakages from the walls at behind.

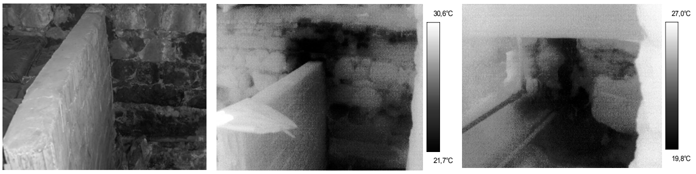


Figure 11 - The colder parts show the wet areas of the wall due to the water leakage from the walls at behind.

4.2 Evaluation of waste water collection and discharge system

A surface water flow arrangement was found to exist in the tepidarium and caldarium sections. The results of the levelling survey was summarized in the map showing the overall surface slopes, their extent and direction as well as the flow pattern of the waste water discharge channel towards the manholes (Figure 12) The waste water was observed to flow from the elevated platforms to the lower levels by means of slopes varying in the range of 1% to 3%. At floor level, the waste water was directed towards the center of caldarium where there was a central waste water collection system surrounding the elevated marble platform. These channels were observed to collect waste water by means of cross falls. These falls were found to vary in the range of 0% and 4%. However, most slopes were found to be below 1% which is not acceptable according to the standards [13]. The risk of ponding areas, especially on slippery surfaces, is dangerous for people. As a result, the surface slopes were found to be unsatisfactory to provide a proper surface water removal at interiors.

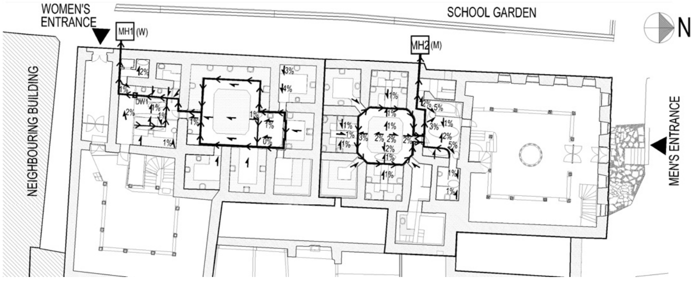


Figure 12 – The map showing the water flow pattern of the waste water discharge channel towards the manholes and the surface gradients of floors.

4.3 Adequacy of roof and surface water drainage systems

The roof and surface-water drainage systems of the building were evaluated in terms of surface grading, discharge capacity and their adequacy.

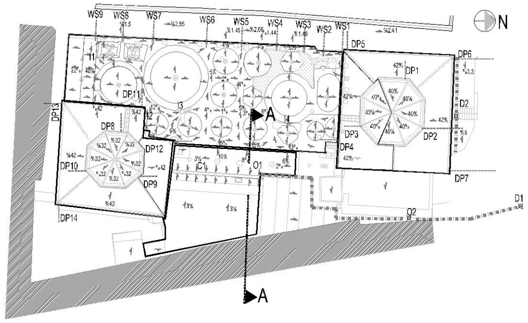


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Figure 13 -. The map showing the direction and extent of surface slopes on the roofs of Sengul Hammam and its immediate periphery.

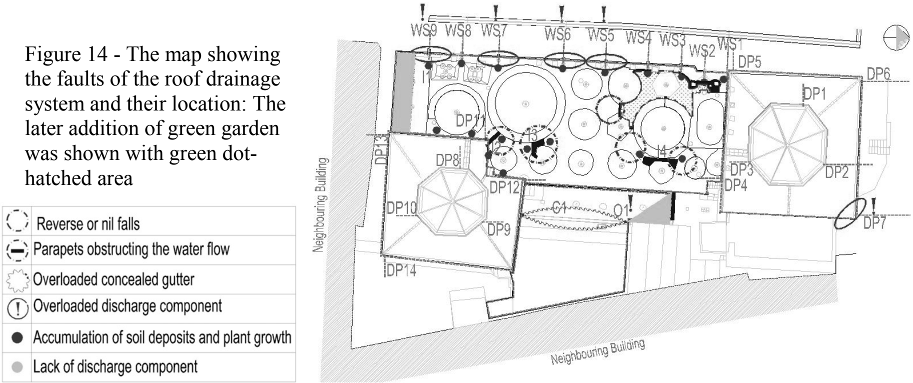
Plans for each of these roof areas, indicating the overall slopes, their directions and extents on roof surfaces in reference to roof drainage components and the immediate periphery of the building are given in Figure 13.

The slopes of the pitched roofs, A1 and A2, were found to be in the range of 32% and 42%. For the roof B1, a surface slope arrangement was found to exist towards the spouts located along the west side consisting of slopes in the range of 3% and 6%. The roof B2 was found to have a roof gradient of 3% from north to south direction with crossfalls towards the interior channel -from east to west and west to east- in the range of 3% and 10%. As the continuation of roof drainage system, the site grading seemed to provide the surface-water removal properly from the immediate grounds of building. At the west, it followed the overall slope of the asphalt-paved street with an average value of 3% from south to north together with the secondary slopes, around 2%, running away from the walls. On the other hand, at the north, the entrance to the men's part was provided at a lower level, -0,90 m, than the street level, which causes the risk of ponded area in the immediate vicinity of the building. This problem was seemed to be solved by means of an area drain, acting like a gully with the slopes varying between 3% and 5% towards the drain, collecting and then, discharging water to the city network (Figure 13).

The present conditions of the roof was determined to be far from performing up to the standards expected from a satisfactory drainage system owing to improper restoration works, poor maintenance and unconscious interventions of the operators. The faults found were summarized as follows:- (Figure 14).

- All discharge components serving the roof areas had, in one way or another, become disfunctional: All spouts were observed to suffer from the accumulation of soil deposits and plant growth, obstructing the free discharge. In addition, all spouts, zinc gutters and downpipes were observed to be severely-deteriorated. The spouts WS1, WS4, WS5 and WS7 were partially lost apparently as a result of wrong restoration practices. Their original dimensions and geometry were also observed to be mostly-changed due to the recent improper repairs with cement mortars and the replacements with the new ones. Almost all metal components were observed to rot and lost their functions.

Figure 14 - The map showing the faults of the roof drainage system and their location: The later addition of green garden was shown with green dot-hatched area



- The reverse or nil falls were found to cause local ponded areas on the roof.
- The regions at the south of the roof B1 and at the north of the roof B2 were also the risky areas due to the lack of discharge components. Ponding and/or overflowing from the eaves level, therefore, were inevitable for these regions.
- .The rainwater collected on the neighbouring building at the east, was observed to be discharged on to the roof of the firewood storage. This added a considerable drainage load to the roof B2, in other words, to the interior channel and drain, O1 (Table 1).

- The roof map in Figure 15, showed that the discrete effective areas feeding the individual discharge components were not consistent with the flow dimensions of the relevant spouts due to the improper surface grading of the roof and the parapets blocking the water flow towards the discharge components (Figures. 14 and 16). The calculations clearly exhibited this uneven distribution of rainwater loading to the discharge components and inadequacy of the discharge capacity of the present drainage system on quantitative basis for the as-is case (Table 1; see also the roof areas in brown, blue and pink feeding the spouts WS5, WS6 and WS7 in Figure 15). The spouts WS5, WS6, WS7, WS9 and the downpipe DP7, were overloaded considerably (Table 1, Figure 17) while the spouts WS1, WS2, WS3 and WS8 working undercapacity (Table 1). The areas suffering from the roof drainage faults, such as overflowing of rainwater from the eaves, eaves gutter, downpipes and waterspouts were detected as cold and damp areas by infrared images. The lower parts of the walls on the axis of downpipes and waterspouts were found to be damp and cold by IRT, due to the evaporative cooling (Figure 18a). The height of cold areas has been detected extending towards the discharge components (Figure 18b).
- Another reason causing such uneven distribution of rainwater loading to the spouts was a green garden with 22m^2 area as a recent unconscious addition to the roof B1 (Figure 14). This garden was added by the personnel of the operator for growing some vegetables by taking advantage of the heat and rainwater of the roof. This garden area surrounded by a concrete parapet of 40cm height without any discharge component also acts like a pool entrapping the rainwater and, without doubt, causing serious dampness problems at both interiors and exteriors.
- Some cracks were also observed on the mesh-reinforced concrete surfaces following the slopes and on domes of the roofs B1 and B2, without doubt, causing water leakages into the sublayers and heat loss from the interiors.

Ponding on roof surfaces and/or overflowing from the eaves level, therefore, were concluded to be inevitable due to these faults summarized above. Such accumulations and overflows have potential for absorbing and retaining rainwater in the structure, as detected in infrared images (Figures 16-18), where it should otherwise be rapidly discharged.

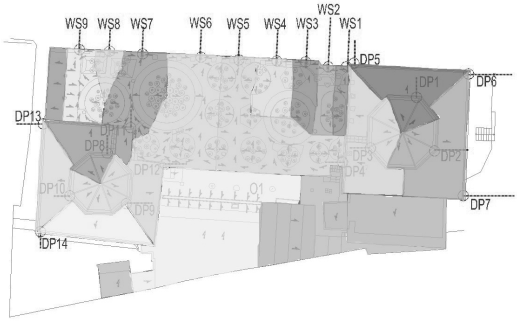


Figure 15.- The roof map of the as-is case, prepared according to the results of levelling survey, showed that the discrete effective areas feeding the individual discharg components were not evenly distributed.

Figure 16- The IR image of the selected region from the roof above the women's part, showing the parapet cutting the water flow, soil accumulation in front of the inlet and and the gradualdecrease of surface temperatures towards the inlet exhibited the potential for absorbing and retaining rainwater

Figure 17 - Darker areas indicate the water penetration problem between the spouts WS6 and WS7 due to the overflowing from the roof eaves level. Severe material loss together with salt deposits and biological growth overlap with the colder areas.

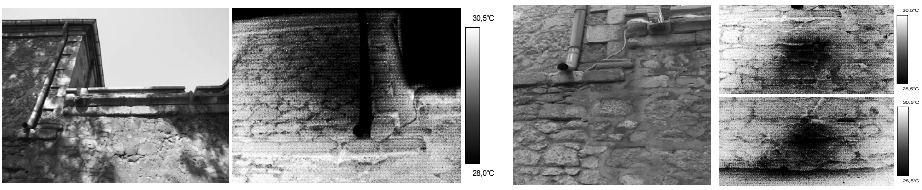


Figure 18 – (a)The detached areas close to the rainwater downpipes were detected as colder areas; (b)The lower parts of the wall corresponding to the axis of the downpipe and the waterspout were found to be cold and damp.

The ideal case was based on an assumption that the 8cm-thick mesh reinforced concrete layer together with the parapets and green garden were removed and the roof was recovered with layers of compatible roof plasters. An even distribution of rainwater loading was tried to be achieved for each discharge component. As much as the present surface geometry allowed, the arrangement of roof slopes were redesigned as shown in Figure 19. Here, the direct discharge from the pitched roofs onto the roof B1 was assumed to be prevented by diverting water to the surface-water drainage system by means of properly-sized downspouts and eaves gutter. According to the calculations and recommended values given in the standards[8],[10], the pitched roofs A1 and A2 should be drained by 21 downpipes in total, with 70mm in diameter located at four sides, and by eaves gutters with 200mm in diameter. In addition, two outlets, O1 and O2, should serve together for the water discharge in acceptable ranges from the interior channel, C1 (Table 1).

Table 1. Results of roof drainage calculations: The spouts which are not enough to cope up with the individual roof runoff rate for the as-is and ideal cases were shown in bold and red.

AS-IS CASE | IDEAL CASE

Roof Spouts	A_R	A_T	Sizes width x height	Qo	Q_{TO}	Q_R	O_{RT}	Roof Spouts	A_R	A_T	Sizes width x height	Qo	Q_{TO}	Q_R	O_{RT}
	(m²)	(m²)	(cm)	(l/s)	(l/s)	(l/s)	(l/s)		(m²)	(m²)	(cm)	(l/s)	(l/s)	(l/s)	(l/s)
WS1	24	657	8.5 x 7.5	1,18	**10,2**	0,68	**18,2**	WS1	74	589	10.0 X 9.0	1,82	16,4	0,99	13,3
WS2	17		9.0 x 7.0	1,13		0,42		WS2	19		10.0 X 9.0	1,82		0,49	
WS3	26		8.5 x 5.5	0,74		0,62		WS3	51		10.0 X 9.0	1,82		1,36	
WS4	35		9.5 x 6.5	1,06		0,82		WS4	65		10.0 X 9.0	1,82		1,76	
WS5	206		6.0 x 11.0	**1,48**	<	**5,79**		WS5	58		10.0 X 9.0	1,82		1,58	
WS6	162		10.0 x 7.0	**1,25**	<	**4,56**		WS6	93		10.0 X 9.0	**1,82**	<	**2,54**	
WS7	124		12.0 x 6.5	**1,34**	<	**3,55**		WS7	101		10.0 X 9.0	**1,82**	<	**2,79**	
WS8	14		9 x 6.5	1,01		0,38		WS8	14		10.0 X 9.0	1,82		0,37	
WS9	49		9 x 6.5	**1,01**	<	**1,4**		WS9	47		10.0 X 9.0	1,82		1,33	
DP7	62		Φ=10	**1,79**	<	**1,85**	1,85	DP7	31		Φ=7	0,93		0,93	0,93
C1	325	325	28 X 12.5	**8,35**	8,35	**9,74**	9,74	C1	275	245	28 X 12,5	8,35	8,35	8,26	8,26
O1	325	325	18 X 12.5	**5,37**	5,37	**9,74**	9,74	O1	138	138	18 X 12,5	5,37	5,37	4,14	4,14
								O2	138	138	18 X 12,5	5,37	5,37	4,14	4,14

QO: the flow capacity of an outlet; QTO: the total discharge capacity of the spouts serving each roof area; AI: the discrete effective areas feeding individual spouts; AT: the total effective area of each roof under study; QR: the rate of runoff from each effective area feeding individual spouts; QTR: the total runoff from each roof under study.

In case of ideal surface conditions, the reasonable flow dimensions for most spouts, WS1, WS2, WS3, WS4, WS5, WS8 and WS9 seemed to be 10cm x 9cm in width and depth, with the discharge capacity of 1.82 l/s. The larger dimensions were needed for the spouts WS6 and WS7 with flow dimensions of at least 11 x 11 cm in order to cope up with the roof runoff 2.63 l/s (Table 1). The total discharge capacity of the spouts with ideal flow dimensions, 16.4 l/s, was also enough to handle the total roof runoff rate, 13.3 l/s. The results also showed that the spouts, WS1, WS2 and WS8 may act as an overflow valve in the event of blocked or partially blocked spouts nearby, on condition that lateral flow between the spouts is duly provided by future improvement work. In addition, a temporary addition of an eaves gutter and a downpipe, DP22, was recommended at the south façade of the roof B1 in order to prevent the free overflowing from the eaves level and severe deteriorations on to the wall surfaces.

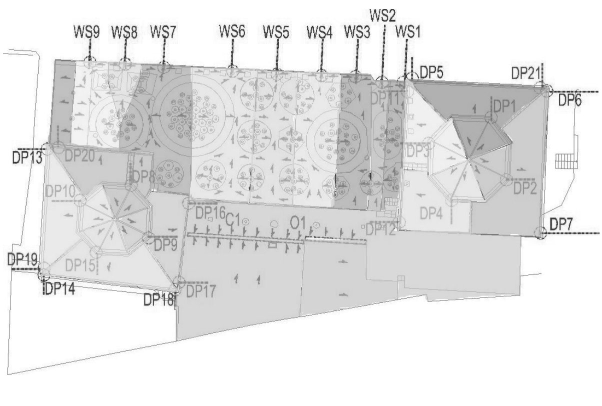


Fig.20. The roof map of the ideal case showing the discrete effective areas feeding individual discharge components.

The surface slopes and directions forming the site grading of the immediate grounds were found to be running away from the building periphery with the rates between 2% and 5%. In practice, these ranges are acceptable for a proper surface water removal [13].

The locations of the area drains and their capacity should be checked for the ideal case due to the additions of new downpipes directly discharging water to the surface-water drainage system of the immediate grounds.

5 Conclusion

The study showed that the original water reserve capacity of the hammam structures and the amount of water consumed by one person can be calculated by the help of some assumptions and acceptances given in the contemporary standards. This data is needed for the definition of the characteristics of the original hot and cold water piping system, the assessment of their adequacy and for their improvement. The calculations used in this study was planned to apply to the other hammam buildings to achieve a reliable data on the water supply and storage capacities of the historical hot and cold water supply systems. In case that original hot and/or cold water supply system was hidden in the stone masonry, their detection can be done by the scanning of wall surfaces by infrared thermography for the examinations.

The waste water discharge system had become disfunctional due to inadequate and reverse falls and inadequate flow dimensions of water channels/drains., in turn causing ponded areas on the slippery marble surfaces. It is clear that a proper surface with a minimum of 2% falls towards the waste water collection channels and properly-sized open channels are necessary for satisfactory waste water drainage in Sengul Hammam. The proper dimensions of channels and floor drains are planned to be calculated as further studies for the improvement of the present conditions of the waste water discharge system.

At present, there were serious dampness problems arising from certain roof drainage faults while the surface-water drainage system appeared to function properly. The study has shown up the priorities for the improvement of the roof drainage system and maintenance program particular to the building: (a) the discharge capacities of the discharge components should be improved by increasing their flow dimensions; (b) the eaves gutter and downpipes forming the peripheral drainage system for the pitched roofs should be replaced with the properly-sized ones; (c) a second drain/inlet is essential for the adequate discharge of water accumulated in the interior channel of the roof B2 and also for acting as an overflow drain in case any one of them becomes blocked; (d) the green garden and the parapets as later additions blocking the water flow should be removed; (e) the direct discharge from the pitched roofs onto the roof B1 should be prevented by diverting water to the surface-water drainage system by means of new downspouts. This is also necessary to provide a proper discharge from the four sides of the pitched roofs; (f) the extreme loading from the roof of neighbouring building at the east of the roof B2 should be prevented; (g) soil and plant deposits blocking the water flow from the spouts should be cleared to discharge freely; (h) the reverse falls in front of spout openings and inadequate surface falls should be levelled properly for proper water runoff; (i) the cracks on concrete surfaces should be repaired to provide a smooth surface on the roof. In addition to these improvements, (j) a temporary solution by means of an additional/temporary eaves gutter and a downpipe is required at the south façade of the roof B1 in order to eliminate the free overflowing from the eaves level. Following these urgent interventions, preventive measures are also essential for a pond-free drainage system and the survival of the building, involving: (k) regular cleaning of discharge components should be provided. For future improvements: (l) the rehabilitation of the surface grading was appeared to be difficult due to the restrictions of material selection for repairs with compatible roof plasters above the concrete base. This incompatible layer of mesh-reinforced concrete should definitely be removed from the roof and then the roof should be covered with the layers of compatible roof plasters in the context of a well-planned conservation program developed by the structural engineers and conservation experts; (m) any subsequent intervention and its effect on the discharge system should be checked by means of roof drainage calculations.

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