# A NEW LABORATORY SCALE APPARATUS FOR EVALUATION OF SPORTS FIELD DRAINAGE PROCESS

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**Abstract -** Sports field drainage has direct effects on quality of sports organization and increasing participation of people to sports facilities. Specifically, there were great numbers of cancellations regarding football organization due to insufficient drainage which was not to be removed fast enough from field surfaces during the play. This study aimed to develop a new lab-scale apparatus to investigate process of rainfall-drainage in the soil of sports field. The apparatus include two main parts which are rainfall simulator (RS) and drainage tank (DT). Simulating natural rainfall is considerably significant for especially laboratory-scale studies. The rainfall are used to simulate natural rainfall conditions at various intensities. Although most of the simulators were designed for constant intensity-rainfall, in this study various rainfall intensities were produced ranging from 25 mm/h to 55 mm/hr. The spatial uniformity of the artificial rainfall is sufficiently accurate to simulate the natural rainfall event. The drainage tank has two identical drainage compartment with different drainage layers. During the experiments drained water from the compartments were measured and drainage water hydrographs for corresponding rainfall hyetograph were recorded. The initial performance of experimental setup showed that it is sufficient to simulate natural rainfall and measure drainage water from each tanks. Initial results also showed that drainage layers in the compartments are distinctly effective on rates of water drainage through the layers.

**Index Terms -** Drainage, Rainfall Simulator, Sports Field.

## I. INTRODUCTION

The drainage of sports field is significant for access to sport activities and increasing participation of people to the sports facilities. In recent years, numerous sports organization were cancelled due to insufficient drainage of surfaces of sports field during and after the rainfall. These organizations take attention of big crowds all over the world and has social and economic impacts on hosting countries. Therefore, effectiveness of drainage process which is intended to remove excess rainfall from the surface of the filed as fast as possible, is essential engineering issue that need to be investigated. Many studies were focused on this topic and they suggested to improve drainage capacity of sports field [1], [2], [3]. Some studies are related to the improvement of root zone drainage characteristics [1],[3],[5],[6],[11]. Different from the above studies, James et al. (2007) stated that mole drainage is an alternative drainage technique for sports field. Similarly, sand slit drainage was studied by Cereti et al. (2004) as an alternative drainage technique. Taylor et al.(1993, 1997) investigated water retention curves (Soil water content- Pressure) for different root zone layers and they measured water content in different depths to understand which root zone is better for drainage. To better understand infiltration process of sports field drainage, several researchers have focused on the relationship between soil characteristics and amount of drainage, principles and gradation of drainage layers and saturated-unsaturated flow characteristics through water movement [4],[7],[10]. In addition, simulating natural rainfall is considerably significant for especially laboratory-scale studies. Many researchers were concerned with rainfall simulators and they investigated drainage, soil erosion and soil crusting by using simulators [17], [18], [19], [20], [21], [23]. The primary purpose of rainfall simulator is to simulate natural rainfall as accurately as possible for evaluation of soil hydrological process during drainage.

In this study, the main objective is to investigate and improve drainage conditions in sports fields using laboratory scale rainfall simulator apparatus that were also developed in the same study.

## II. MATERIAL AND METHODS

### A. Experimental Setup

A laboratory setup of apparatus is presented in Figure 1. The main components are: Rainfall simulator (RS) which consists of downward-oriented spraying nozzles fixed on 5.5x3.5m main frame; rainfall mesh located 1 m beneath the nozzle and drainage tank which includes two identical 1.5 m x1.3 m compartments. There are a 100 lt water tank supplies water to the system with 2 cm diameter galvanized pipes and PLC control panel in the front of the apparatus. This panel controls a pump that can apply pressure between 0-65 bar that produce rainfall with changing intensity from 25-55 mm/hr. The RS uses the Spraying Systems Fulljet nozzle. It is able to work between 0-10 bar pressures. The wire mesh is located 1m distance beneath the nozzle that it is appropriate 2.4 m distance above the ground surface of drainage tank in order to achieve terminal velocity of rainfall

drops similar to that of natural rainfall. That 2.4 m distance is enough for a rainfall dropping from the mesh surface with zero initial velocity to reach terminal velocity [18]. Drainage tank (DT) with the dimensions of 1.5x1.3m has four drainage perforated pipes at the bottom of tank which were located 30 cm distance intervals. There are two troughs on the apparatus: upper one is located around the mesh, the lower is located around the surface of DT. These through collect excessive rainfall water which does not reach to the DT's surface. Also, this water is measured together with drained water during the rainfall experiment.

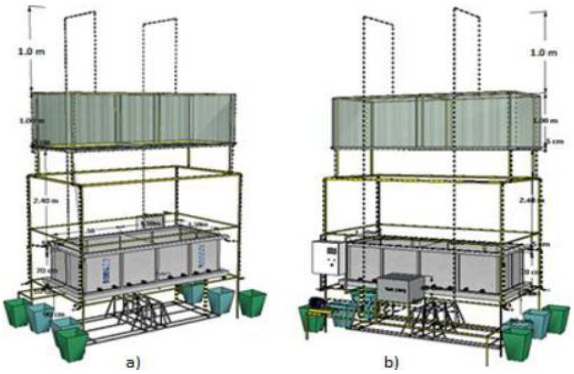



**Figure1. Schematic View of Experimental setup (a) Rear view (b) Front view**

### B. Design Hyetograph

For each experiment a design hyetograph is defined which represent characteristic rainfall of the hydrological system for the area nearby sports field [36]. This hyetograph is obtained by considering the historical precipitations in the relevant region. Design precipitation hyetographs are determined from Intensity–Duration -Frequency (IDF) relationships. There are basically two ways to obtain design hyetograph from IDF analysis in the literature: Alternating block method (AB Method) and Instantaneous Intensity Method (II Method) [25]. Experimental hyetographs were developed by using AB Method in the present study because the AB method is simple and easy to apply comparing to II method.

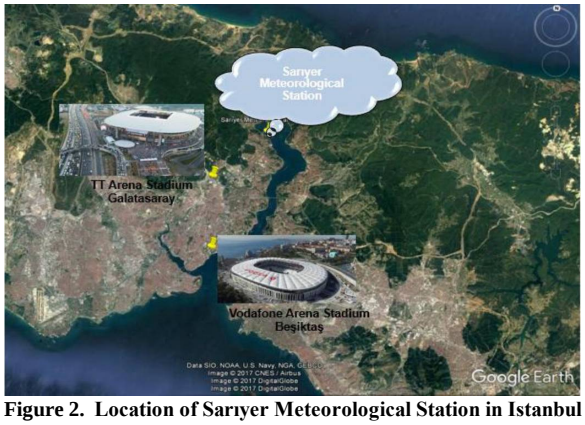



**Figure 2. Location of Sarıyer Meteorological Station in Istanbul**

The football fields of Galatasaray and Beşiktaş were chosen as study area for which the closest meteorology station is Sarıyer meteorological station located in northern Istanbul. IDF data of this meteorology station is used to produce design hyetographs. Figure 2 shows both the location of Sarıyer station and locations of Galatasaray TT Arena and Besiktas Vodafone Arena which are two of the biggest football stadiums in Istanbul.

## III. RESULT AND DISCUSSION

In this study, drainage process of sports field was evaluated by using a newly developed experimental apparatus. The performance of the apparatus was evaluated by investigating rainfall uniformity which is a significant criteria in rainfall simulations to resemble the natural rainfall and to obtain unbiased drainage outflow hydrograph from DT.

### A. Rainfall Uniformity

Rainfall spatial uniformity directly shows the performance of the RS. The most commonly-used technique is the uniformity coefficient (CU, %) determined by Christiansen (1942) as follows using Eq. (1) :

$$CU=\left(1-\frac{\sum_{i=1}^{N}\left|x_i-\bar{x}\right|}{N\bar{x}}\right).100 \qquad (1)$$

where $x_i$ is rainfall depth at location $i$, $\bar{x}$ average rainfall depth and N the number of points in which rain gauges are located on the DT to collect rainfall. When CU is greater than %80, the rainfall can be accepted as a uniform rainfall ([25], [26]). Luke et al. 1993 expressed that, for larger plots, rainfall can be accepted as uniform if CU is greater than %70.

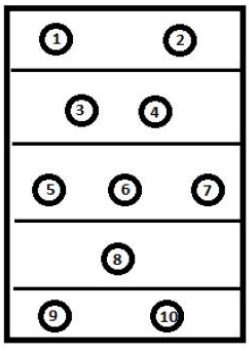



**Figure 3. Schematic view of the locations of rain gauges on DT's surface.**

Figure 3 shows the schematic view of the locations of rain gauges on DT's surface. Uniformity experiments were conducted for 10 min for 4 different rainfall intensities and results were summarized in Table 1.

| Rainfall Intensity (mm/hr) | CU |
|---|---|
| 25.00 | 75.00 |
| 38.00 | 84.53 |
| 48.00 | 84.63 |
| 55.00 | 87.08 |

**Table 1. Coefficient of Uniformity for different rainfall intensities**

### B. Drainage Outflow

DT is main part of the newly-developed apparatus which enables to measure drain water for corresponding hyetograph at the same time. DT consists of two identical tanks which can be prepared with different drainage layers covered by sport grass. For the first experiment, DT was prepared with different drainage layers as seen Figure 4. Right side of DT (Section-A) tank was prepared by packing layers of root zone (15 cm), 1.2-2.5 mm fine pebble (15 cm), 5-8 mm gravel (15 cm), and 12-15mm coarse gravel (5 cm) o total depth of the drainage zone is 50 cm from top to bottom. Similarly, left side of DT (Section-B) was packed layers of root zone (15 cm), 0.6-1.2 mm coarse sand (15 cm), 5-8 mm gravel (15 cm), and 12-15mm coarse gravel (5 cm). Therefore, there are four drainage pipes with 7 cm diameter for each part of the DT.

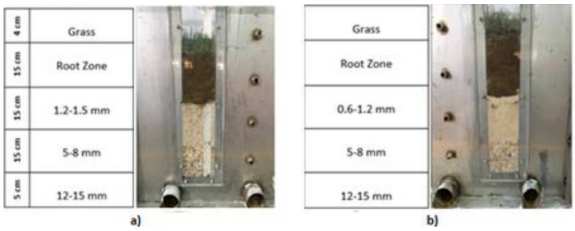



**Figure 4. a) Right-cross-section of DT, b) Left-cross-section of DT**

These drainage layers were subjected to RS with a hyetograph with 5 year return period which was obtained using IDF curves for Sarıyer meteorological station. Simulated rainfall intensities were between 25-55 mm/hr as given in Figure 5.

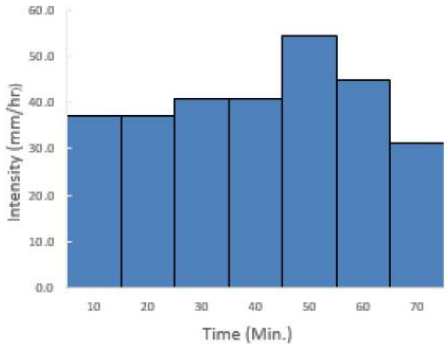



**Figure 5. Hyetograph for Sarıyer Meteorological Station for 5 year return period.**

Figure 6 shows the drained water hydrograph which was measured in every 5 minutes during and after the experiment. Moreover, the blue line hydrograph represents right side of DT and the red line represents the other side.

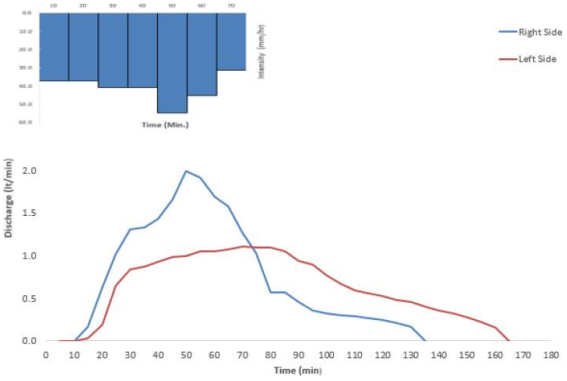



**Figure 6. Outflow hydrograph for each cross-section for given hyetograph.**

## CONCLUSION

In this study, the apparatus was developed to investigate the effectiveness of the drainage process of sports fields. It consists of RS that simulate natural rainfall and DT that represents the drainage process. The initial results show that the apparatus was successfully developed that RS simulated rainfall with acceptable results of uniformity coefficient and cross-sections of drainage layers in DT were accurately and similarly modeled as applied in sports fields. In brief, following conclusions were obtained from this study;

i. The uniformity coefficients (CU) for rainfall intensities of 25, 38, 49, 55 mm/hr were obtained as 75, 84.53, 84.63, and 87.05 percent, respectively. The results showed that simulated rainfall has accurate spatial uniformity over the DT.
ii. Two different drainage layer cross-sections were placed in each parts of DT. These cross-sections were basically same but the second layer of Section-A consists of coarser materials with 1.2-2.5 mm diameter. They were exposed to identical rainfall hyetograph. Drainage outflow hydrograph given in Figure 6 shows that the maximum discharge rate obtained from Section-A is greater than Section-B, and contrarily, the total time of hydrograph is less than Section-B.
iii. The gradation of drainage layer affects “time to maximum discharge” and “shape of the hydrograph
iv. The layer below the root zone is more effective than the subsequent layers in the drainage process.
v. For 70 minutes rainfall, infiltration takes place around 2.5-3 hours in total.
vi. Alternating block method in obtaining the design hyetograph is successful.

In conclusion, initial results determined that the newly-developed apparatus was successfully applied to process of sports field drainage. For future works, crucial and critical rainfall intensity that allows to high quality sports organizations and an applicable standard for the thickness and gradation of drainage layer will be investigated.

## REFERENCES


[1] Adams, W.A., Stewart, V.I. and Thornton, D.J. 1971. ''The Assessment of Sands Suitable for Use in Sports Fields.'' J. Sports Turf Res. Inst. 47:77-86.

[2] Cereti, C.F., Rossini, F., Romoli, F. 2004. ''Improvement of Drainage Capacity in Sports Field'' Acta Horticulture, 661

[3] Davis, W.B., J.L. Paul, and D. Bowman. 1990.'' The sand putting green: Construction and management.'' Publ. No. 21448. Univ. of California Div. of Agric. and Nat. Resources, Davis, CA.

[4] Dogan, A. 1999. 'Three Dimensional Variably Saturated Rainfall Driven Groundwater Flow Model' PhD Dissertation, University of Florida, Florida

[5] Harvey, K. R. 2009. '' Water Flow through Geotextiles Used to Support the Root Zone of Turf grass on Sports Fields'', Master

[6] Harvey, K. R., McInnes, K.J., Thomas, J.C., (2012). ''Water flow Through Sand Based Root Zones atop Geotextiles.'' HortScience, 47(10), 1543-1547

[7] Hillel, D. 1998. 'Environmental Soil Physics' Academic Press. London, 771s.

[8] Hummel, N.W. 1998. ''Which root-zone recipe makes the best green? Golf Course Manage.'', 66(12):49-51.

[9] James, I. T., Blackburn, D. W. K., Godwin, R. J. 2007a. ''Mole drainage as an alternative to sand slitting in natural turf sports surfaces on clays. Soil Use and Management'', 23, 28–35

[10] Jury, W.A., W.R. Gardner, and W.H. Gardner. 1991. ''Soil Physics.'', 5th ed., John Wiley & Sons, New York.

[11] Prettyman, G. W., McCoy, E. L. 2003.''Profile Layering, Root Zone Permeability, and Slope Affect on Soil Water Content during Putting Green Drainage.'', Crop Science, 43, 985–994

[12] Shaddox, T. 2004. '' Investigation of Soil Amendments for Use in Golf Course Putting Green Construction.'', Doctor of Philosophy Dissertation, University of Florida, Florida

[13] Taylor, D.H., and S.D. Nelson. 1997.'' Water retention in root-zone soil mixtures of layered profiles used for sports turf.'', HortScience 32(1):82-85.

[14] Taylor, D.H., S.D. Nelson, and C.F. Williams. 1993. ''Sub-root zone layering effects on water retention in sports turf soil profiles.'', Agron. J. 85:626-630

[15] U.S. Golf Association Green Section Staff. 1993.'' USGA recommendations for a method of putting green construction.'', USGA Green Sect. Rec. 32(2):1-3.

[16] Waltz Jr., F.C., Quisenberry, V.L., McCarty, L.B. 2003. ''Physical and Hydraulic Properties of Root Zone Mixtures Amended with Inorganics for Golf Putting Greens'' AGRONOMY JOURNAL, Vol. 95

[17] Lassu, T., Seeger, M., Peters, P. and Keestra, D.S. 2015 'The Wageningen rainfall simulator: set-up and calibration of an indoor nozzle-type rainfall simulator for soil erosion studies'. LAND DEGRAD DEVELOP.

[18] Carvalho, S.C.P, Joao, L.M.P. and Isabel, M. 2015. 'Increasing the rainfall kinetic energy of spray nozzles by using meshes'. LAND DEGRAD DEVELOP.

[19] Paige, G.B, Stone, J.J. and smith J.R and Kennedy, R.J.'Walnut Gulch rainfall simulator: A computer- controlled variable intensity rainfall simulator'. AMERICAN SOCIETY OF AGRICULTURAL ENGINEER ISSN 0883. Vol.20 (1):25-31.

[20] Hignett, C.T, Gusli, C.T, Cass, A. And Besz. W. 1995. 'An automated laboratory rainfall simulation system with controlled rainfall intensity, raindrop energy and soil drainage.' SOİL AND TECHNOLOGY. 31-42.

[21] Abudi, I., Carmi, .G. and Berliner, P. 2012. 'Rainfall simulator for field runoff studies. JOURNAL of HYDROLOGY.

[22] Iserloh, T., Ries, B.J, Arnaez, J. Butzen,V. Cerda, A. and Echeverria, M.T. 2013. 'European small portable rainfall simulators: A comparison of rainfall characteristics. CATENA 110: Pages 100–112.

[23] Aksoy, H., Unal, E., cokgor, S., Gedikli, A., Yoon, J., Koca, K., Inci, B. and Eris, E. 2012 'A rainfall simulator for laboratory-scale assessment of rainfall runoff sediment transport processes over a two dimensional flume. CATENA. 98: 63-72.

[24] Neff, E. L., 1979. 'Why rainfall simulation?' In: Proceedings of rainfall simulator workshop. Tuscon, AZ: US Depertmant of Agriculture.

[25] Chow, V. Te, Maidment, D. R., Mays, L. W., 1988. 'Applied Hydrology' McGraw – Hill Book Company, United States,pp 465-470.

[26] Moazed, H., et al., 2010. Effects of climatic and hydraulic parameters on water uniformity coefficient in solid set systems. Journal of Applied Sciences, 10 (16), 1792–1796.

[27] Luk, S.H., Abrahams, A.D., and Parsons, A.J., 1993. Sediment sources and sediment transport by rill flow and interrill flow on a semi-arid piedmont slope, Southern Arizona. CATENA, 20 (1–2), 93–111.


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