LIGHTWEIGHT CONCRETE DRYING TIME

Abstract: The present dissertation has the aim to evaluate the drying rate of lightweight concrete in function of the coarse aggregate type.

Three different concrete were produced changing the type of lightweight aggregate that was used, which were granulated expanded cork, expanded clay and pumice stone. An ordinary concrete was also made (reference concrete) in which the coarse aggregate was crushed limestone.

After being removed from the mould, the specimens were placed in two distinct environments, so that it could be possible to evaluate its influence on concrete's drying rate. All the specimens were weighed monthly in order to evaluate a loss of water on concrete and its evaporation rate. It was also measured the variation of water content at different depths of the specimens to determine the dryinf profile.

Keywords: lightweight concrete; lightweight aggregates; shape mould; substratum; density; loose bulk density; water absorption; water content; relative humidity.

1. INTRODUCTION

Nowadays, the use of lightweight concrete is increasing, not only for structural applications, but also for other purposes, such as rehabilitation or pavement filling.

The application of lightweight concrete on pavements is increasing, mainly due to the lower self weight compared to the ordinary concrete, making possible the decrease of loading in the structure. However, one of the major problems that concrete has is the time that it takes to dry out, meaning, the time that the water takes to come out of the concrete, delaying the coating and causing anomalies on this one. Since, the drying process is slow, it is necessary to know the water content that is acceptable in the concrete so there isn't any problem when a coating, that is sensitive to humidity, is applied.

This dissertation has the aim of knowing the water content of concrete, throughout time, in order to estimate how long it does take to dry depending on the lightweight aggregate used.

2. LIGHTWEIGHT CONCRETE

2.1. Definitions

Lightweight concrete is defined according to NP EN 206-1 [1] as a concrete that has a density, after oven drying, that isn't larger than 2000 kg/m^3, total or partially produced with porous structure aggregate.

The main difference between lightweight concrete and normal concrete is the lower density mass, besides its distinguishable thermal and durability characteristics.

In addition, the standard NP EN 13055-1 defines lightweight aggregate as having a particle density not exceeding 2000 kg/m^3 or a loose bulk density not exceeding 1200 kg/m^3.

2.2. Historical Background

The usage of lightweight materials, such as pumice-stone, comes far away back since the Romans, when they mixed these aggregates with binders made of volcanic ashes and lime to get a concrete with low density.

Throughout history, several constructions were built using lightweight concrete. Many of them are, to this present day, in very good conditions, mostly for its durability, as for example, the Roman Pantheon that was built between 110 and 125 d.C. [2].

Lightweight concrete was used, throughout time, on different applications, for example naval construction. But today this material is used in all kinds of structures as bridges; buildings, oil platforms, among others.

The usage of lightweight concrete goes beyond structural function. This material is used to improve the already existing structures, namely pavements, due to its lightness and thermal and acoustic isolation characteristics.. Nowadays, many buildings are built using lightweight concrete to fill up floors. It is this type of usage that this dissertation is about.

3. FLOOR'S HUMIDITY

In a floor, humidity is not uniformly distributed through the concrete's thickness. By the surface, and in contact with the environment, it shows lower values and it increases into concrete's interior. On the other hand, the application of an impermeable coating over the concrete surface diminishes, or even stops the drying process. In this way, the humidity in the interior of the concrete tends to distribute itself and can reach values higher than those accepted on the surface that is in contact with the coating, leading to the detachment and damage of the applied material.

It is necessary to know how the humidity spreads through the concrete's substratum thickness; to define the humidity level that is acceptable for the coating application and to select methods that allows estimating the duration and rate of the drying process.

In the following table it is shown a summary of the drying times adopted by some organizations, so that the concrete's surface reaches a satisfactory humidity level.

Table 1- Recommended drying times (adapted from [5])

Organization	Recommended drying time
ASTM - American Society for Testing Materials	6 weeks to 6 months
CRI - Carpet and Rug Institute	12 to 16 weeks for rubber textile coating application
WFC - World Floor Covering Association	28 days (not a very strict criteria)
RFCI - Resilient Floor Covering Institute	6 weeks for any kind of sensitive to humidity coating
PCA - Portland Cement Association	8 weeks minimum

4. EXPERIMENTAL PROCEDURE

4.1. Measurement of drying time

The characterization of the concrete's drying process has been an object of several experimental studies by several investigators. The methods used can be classified in three groups: to check the concrete weight change; destructive methods (for example the introduction of probes into the concrete to assess the humidity) and measurement of the relative humidity / water content [3].

4.2. Methods to measure the concrete's humidity

There are several types of tests, standardized, to evaluate the humidity level in a concrete's substratum. These can provide both qualitative and quantitative data. However, the main testes used to evaluate the humidity level are described on the standard ASTM E 1097-97 [4] (Table 2) that describes the procedures to determine the water content present or emitted through the concrete layer, establishing the criteria to evaluate the concrete's conditions, in order to aplly the coating that is sensitive to humidity.

Table 2 – Tests for humidity measure [5]

Qualitative tests	Quantitative tests
Plastic leaf	Electrical resistance
Glued plaque	Moisture meter
Qualitative calcium chloride	Anhydrous calcium chloride
Mathematical test	Relative humidity

4.3. Aggregate description/characterization

The characteristics of lightweight concrete depend basically from the experimental characterization of the used aggregates in these same concretes. So, it was necessary to describe the materials relatively to its particle size distribution; loose bulk density; particle density and water absorption. The determined characteristics of the aggregates used in this research are indicated in Table 3

Table 3- Properties from the aggregates

Material	D	d	Fineness module	Fines	Loose bulk density (kg/m^3)		Saturated particle density with dry superficie	Water absorption(%)
	(mm)	(mm)		%	compact	Not compact		
Natural sand	2,38	0,149	3,1	0,8	1650	1550	2590	1,2
Argex 2-4	6,35	0,59	4,6	0,9	490	470	700	23,8
Granulated with expadend cork 2-9	9,52	1,19	5,2	0	90	80	150	36,4
Pumice stone	6,35	0,074	3,5	24,3	630	600	790	58,9
Crushed coarse aggregate	6,35	0,59	5,1	0,6	*	*	*	*
* it wasn't established for this aggregate								

4.4. Formulation of the studied compositions

For the research project it were produced several concrete with different types of lightweight aggregates, in order to evaluate the influence of the coarse aggregate on the concrete drying rate. The adopted designations to different concrete are introduced, as followed:

RC- reference concrete;

LCGC- lightweight concrete with granulated cork;

LCEC- lightweight concrete with expanded clay;

LCPS- lightweight concrete with pumice stone.

After performing the preliminary mixtures, the following final compositions were adopted to the used concrete (Table 4).

Table 4- Compositions applied in the production of concrete

	Total water (l/m^3)	Cement (kg/m^3)	Aggregate(kg/m^3)		
			sand	Lightweight aggregate	Crushed stone type 0
RC	230,6	350	610	-	1108,7
LCGC	238,9	350	610	79,9	-
LCEC	271,9	350	610	303,2	-
LCPS	392,2	350	610	358,3	-

For each composition four specimens were made with dimensions of 10x10x10 cm^3. After being removed from the mould, the specimens were subjected to a unidirectional drying process rendering impermeable 5 of its 6 surfaces, leaving only the filling surface exposed to the environment. After the impermeable coating had been dried, the specimens were taken to a room where the environment was controlled and in where they were placed in appropriate conditions until the tests that were going to be performed.

5. ANALYSIS OF THE EXPERIMENTAL RESULTS

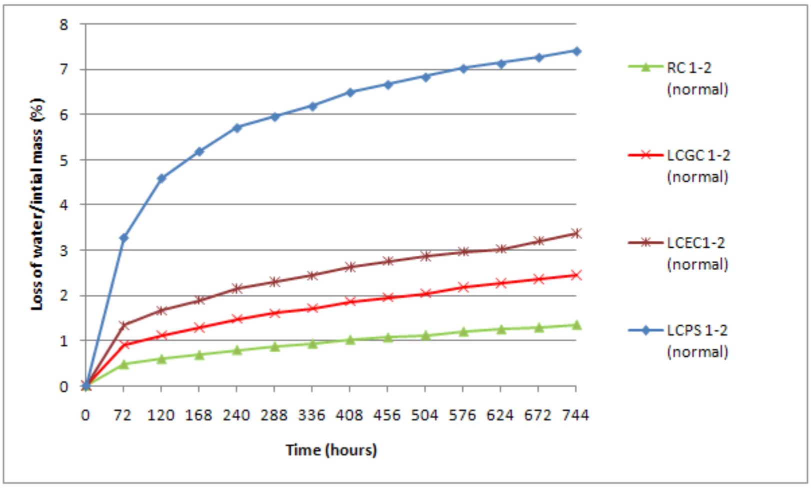
The tests that were performed on the concrete weren't based on a specific standard, but on a set of technical information, which allowed choosing the methods to determine its water content and its relative humidity throughout time.

The specimens were subjected to two distinct environments, meaning that half of the specimens (2 of each type of concrete) were placed on a test room with controlled environment. The other half was placed on a ventilated chamber with controlled temperature (identical to the previous one), so that, it was possible to get some conclusions about the procedures that may accelerate the concrete's drying time.

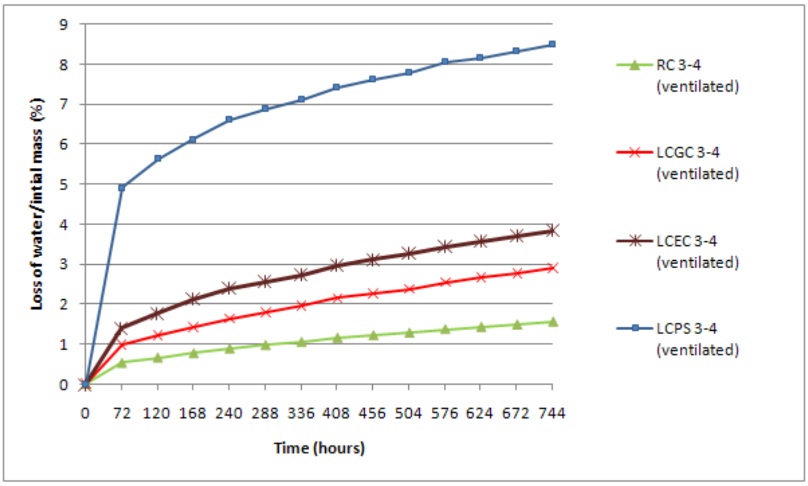
5.1. Loss of water on concrete

To determine the loss of water on concrete throughout time, weighing was made for a month to all the tested specimens. The results obtained are shown in the following graphics.

GRAPHIC 1 – COMPARISON OF MASS LOSS BETWEEN CONCRETES (NORMAL ENVIRONMENT)



GRAPHIC 2- COMPARISON OF MASS LOSS BETWEEN CONCRETES (VENTILATED ENVIRONMENT)



Through the graphics 1 and 2 it is possible to check the differences between the concrete in relation to water loss. The LCPS shows the highest values of water loss / initial mass due to the greater amount of water (incorrectly determined). The differences between the LCEC and LCGC are due to the properties of each lightweight aggregate. As the aggregate supplies water to the system, the concrete that has more water will be subject to greater evaporation presenting a greater loss of water.

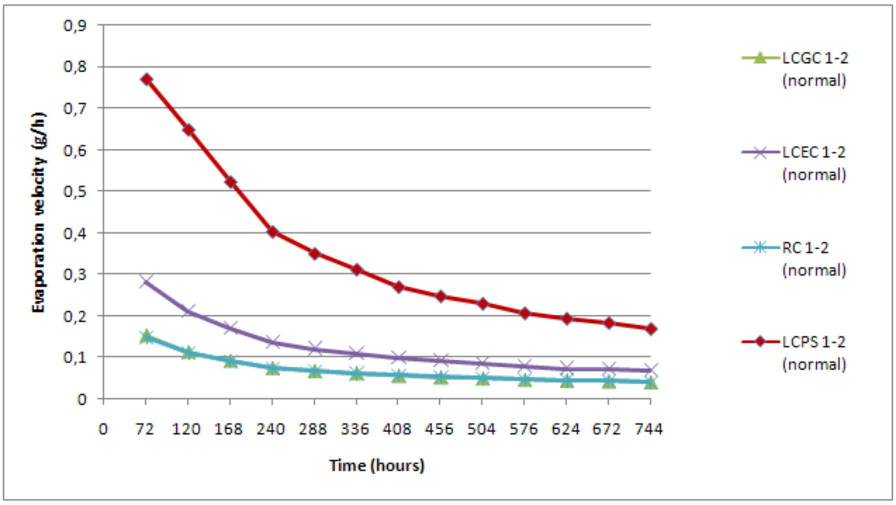
The RC has the lowest values due to having in its composition, a smaller amount of water in there maining concrete.

It is possible verify by GRAPHIC 2 that ventilation accelerates the loss of water on concrete, which may influence more or less depending on the type of lightweight aggregate used.

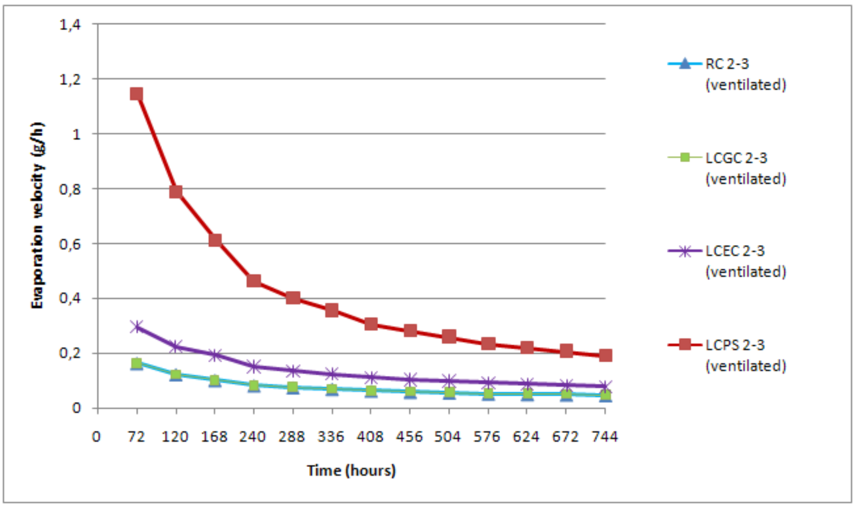
5.2. Evaporation velocity

From the verified values of mass loss, it was possible to determine the evaporation rate, which is stated in grams of water lost in each hour, showed by the different concrete.

GRAPHIC 3- COMPARISON OF THE EVAPORATION RATE BETWEEN CONCRETE (NORMAL ENVIRONMENT)



GRAPHIC 4- COMPARISON OF THE EVAPORATION RATE BETWEEN CONCRETE (VENTILATED ENVIRONMENT)



These graphics show similar conclusions to those on the loss of water. The LCPS velocity is shown as the most significant one.

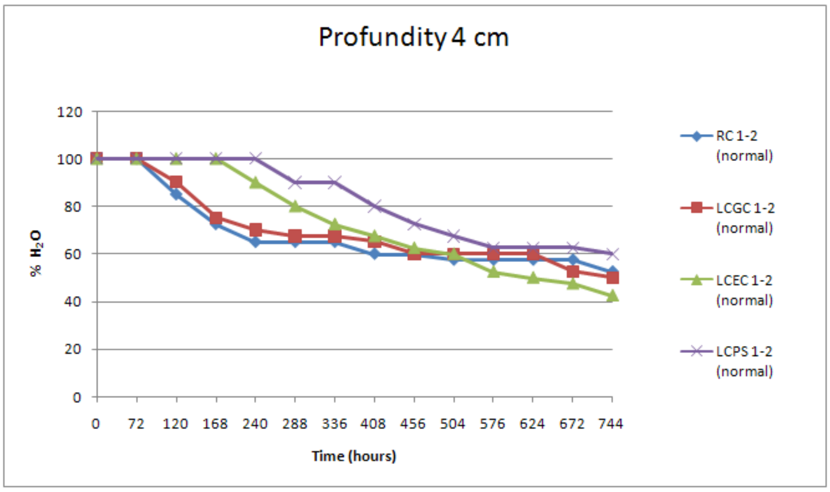
5.3. Water content's variation

To determine the water content's variation in the specimens bulk a moisture meter was used. This equipment measures the percentage of superficial water in a given substance.

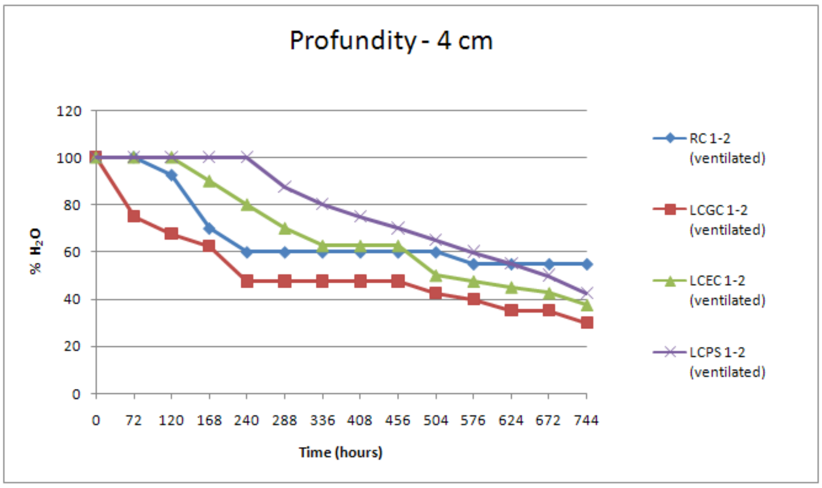
To find out how much water the concrete has lost, several readings were made to all specimens. This process consisted on recording the indicated values on the equipment when the pins were in contact with the concrete's surface. Registers were made in every 2 cm along the specimen's thickness.

From the obtaining results, several graphics were elaborated to show how the water content holds throughout time and in varied thickness. For example, in the following graphics it is possible to show the differences between different concrete within a 4 cm depth.

GRAPHIC 5- COMPARISON OF THE WATER CONTENT BETWEEN CONCRETE- 4 CM (NORMAL ENVIRONMENT)

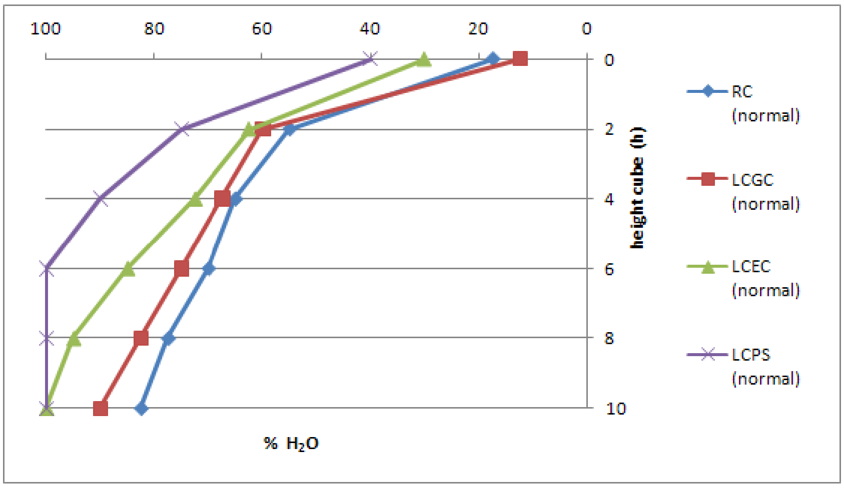


GRAPHIC 6- COMPARISON OF THE WATER CONTENT BETWEEN CONCRETE- 4 CM (VENTILATED ENVIRONMENT)



In the following graphic the approximate humidity contents in depth are shown at the end of 15 days (336 hours).

GRAPHIC 7- APPROXIMATE HUMIDITY CONTENT IN DEPTH (AFTER 336 HOURS)



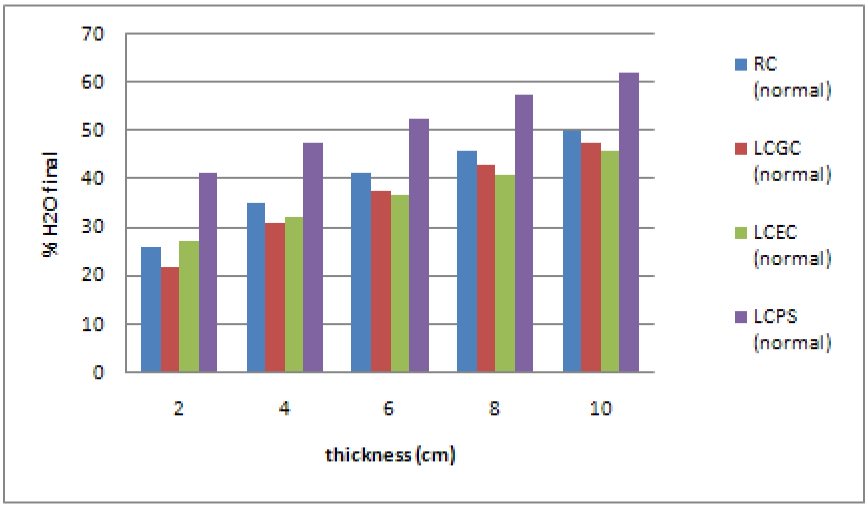
5.4. Final humidity content with different thickness

As it has already been referred, it is important to know the humidity level that is acceptable on a concrete surface, so that water sensitive coating may be applied. After that, humidity is distributed uniformly in the concrete's interior, changing the humidity value on the surface that is in contact with the coating.

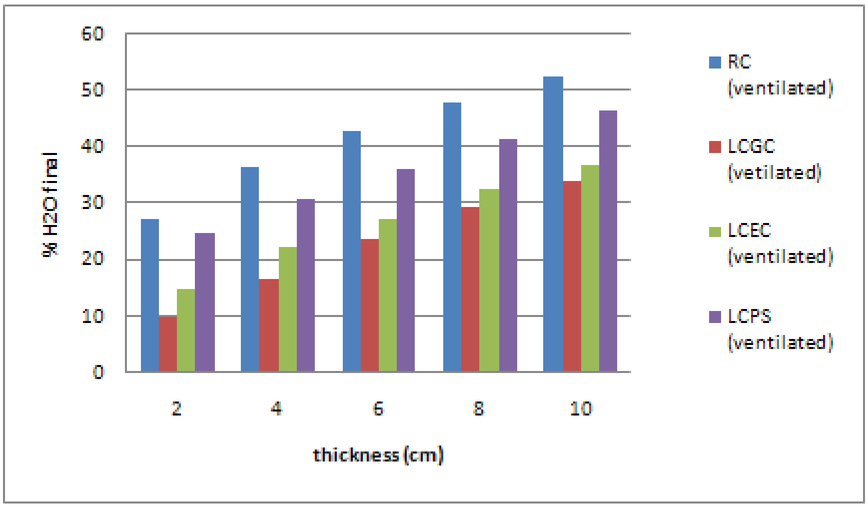
In this way, it was calculated the values referring to humidity content of each concrete, if a waterproof coating was applied and humidity was distributed uniformly in the whole specimen. The was admitted that the humidity content in each depth corresponded to a medium humidity content in a concrete layer with that thickness. So, through the average between the humidity values that referred to the several thicknesses, it was established that the humidity content that concrete would have after applying a coating.

The following graphics are an example of the results reported in this chapter, indicating the humidity content values, after 30 days of drying, in which the different concrete would have in specimens with different thickness, in 2 distinct environments.

GRAPHIC 8- FINAL HUMIDITY CONTENT IN CONCRETE SPECIMENS WITH DIFFERENT THICKNESS AFTER DRYING FOR 30 DAYS (NORMAL ENVIRONMENT)



GRAPHIC 9- FINAL HUMIDITY CONCRETE SPECIMENS WITH DIFFERENT THICKNESS AFTER DRYING FOR 30 DAYS (VENTILATED ENVIRONMENT)



With these graphics it is possible to conclude that concrete that is subjected to ventilation has, in the end, lower humidity contents. LCGC is the one that shows the lowest values. LCPS always shows the highest percentage values of water in relation to lightweight concrete. On the specimens subjected to a normal environment, it is verified some similarity between LCGC, RC and LCEC.

6. CONCLUSION

With this dissertation it was possible to know the influence that lightweight aggregate have in concrete's drying process.

In this way, the conclusion is that the lightweight aggregate that induces a lesser concrete drying time is the granulated cork (LCGC). However, concrete with expanded clay (LCEC), after a while being dried, shows similar values to LCGC. The lightweight aggregate that negatively influences the concrete's drying time is the pumice-stone one, because it shows, in all the results, the highest contents of final humidity.

In relation to the concrete that was subjected to a ventilated environment, it is concluded that these show minor drying time. Ventilation can be a viable method to accelerate the drying process, reducing the final values of water content (after a month) about 10%.

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