RESEARCH ON MICROCLIMATE LIGHT CONDITIONS IN A SCHOLASTIC ENVIRONMENT, BASED ON ADAPTIVE MODEL

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ABSTRACT

This paper shows the results of a deep research, carried out on a scholastic setting and based on a questionnaire, to evaluate the light microclimate and the satisfaction degree of the users.

Through simulations, we have previously identified a number of classrooms where the conditions could be critical, both in terms of over-lightning, glare and disrespected values (suggested by the current normative).

The proposed method consist in using device-made-surveys, a simulation software and questionnaires submission to users of the studied rooms.

The questionnaires, based on an adaptive model, has been developed to detect subjective data (place, visus…) and other information about the setting and its relationship with the users (difficulty in eyesight, year average frequency using light shelf.

The results obtained after the questionnaires' submission, mapped in a chromatic scale that considers each position held by every users, show high degrees of dissatisfaction even if the device-made-surveys has found values considered quantitatively acceptable.

Another simulation shows the possibility of corrective actions, not invasive, in order to control natural light, which results shows a quantitative values reduction from the optimal range followed by a significant improvement in terms of quality of the microclimate light conditions.

The procedure we developed derives by the integration of traditional and experimental methods, evaluating the gap that, in this case, seemed to be too high considering the whole school time.

Keywords: visual comfort, daylight factor, adaptive model, light microclimate.

1. INTRODUCTION

The correct natural lighting system in classrooms, as well as in offices, is necessary to do the visual tasks in all seasons and above all during the daily lesson hours. This lighting must be both in quality and in quantity correct and tied to the kind of job. Such lighting system must always be adequate qualitatively and quantitatively to the type of job.

In the school buildings, in order to maintain the very high values of required standard, we have to control several parameters of light microclimate.

However the above mentioned conditions can have a floating gap from the optimal indices not relievable through the traditional instrumental revisions. The correct use of the natural light influences the physical activities but it is also a stimulus for mental activity. In fact we have an increasing of the working activities and a delay of the tiredness incoming.

The light microclimate is strongly influenced by architectural configurations which consider an opportunity the possibility to use the natural light even if it may be a discomfort when it is not opportunely controlled. So the strongly inhomogeneous lighting environment is often the reason of the occupational astenopy, that in working occupational health and hygiene is called "*disability glare*" [1].

The current trends of the scientific community deal with the determination of indices based on the sensation and the satisfaction of the indoor microclimate by the real users of such spaces, and on the different aspects which have often inquired using methodologies that make wide use of statistics.

In the lightening field it does not exist a clear and defined surveying methodology that can lead to define such indices of analysis, as it happens in case of thermoigrometric microclimate, (by the employment of the indices of sensation PMV and PPD), which can express numerically, and plausibly, what the “satisfaction” of the users towards the environmental conditions will be, considering the continuous improvement of the model [2].

However there are some approaches, having reference to instruments, to simulators and to the use of a dynamic model, which are incomplete in some aspects [3].

The requirements of lighting system in a room vary, as we know, according to the activities that take place in it as well as to the exposure of the building and to the natural light availability. It is necessary a rigorous control of this resource to avoid real discomfort conditions of visual and thermal situations or summer overheating.

The main objective of this research is to carry out the quality in three defined fields, related to the individual, to the economic and environmental implications.

2. OUTLINE OF THE REGULATION

In 2004 the norm called UNI EN 12464:2004 - *Light and lighting - Lighting of work places - Part 1: Indoor work places* is put in effect. It defines the quality criteria of the systems for a good vision, for a correct methodology of measure and for the project criteria was applied [4].

Together to the norm UNI 10840:2007 - *Light and lighting - School rooms - General criteria for the artificial and natural lighting*, are defined the indoor levels of lighting according to the difficulty of the visual tasks [5]. In details in school environments, object of this study, this norm suggests the preference to use the natural light instead of the artificial one, for a better psychophysical balance of the user and a further energy saving [6].

With this aim, the norm UNI EN 15193:2008 – *Energy performance of buildings - Energy requirements for lighting* [7], was applied in March 2008. It defines a numerical indicator of energy requirements for the lighting system to use for the energy certification, and it also gives a methodology for the calculation of the instantaneous energy consumed for the lighting system and the esteem of the total energy efficiency of the building. It is one of the first attempts to isolate the relative use of the lighting system to evaluate its efficiency. The methodology and the format must satisfy the 2002/91/CE Directive requirements on the energy performance of the buildings [8].

The same use, relative to the lighting system, is taken into consideration by the national law, became effective on the 10th July, 2009 inside the national guidelines for Energy Certification [9], in which the calculation of the EPgl (Global Primary Energy) considers: Epi (winter Primary Energy), Epe (summery Primary Energy), EPacs (Primary Energy sanitary warm water), and also EPill (still not in law).

3. A CASE STUDY

In this research we analysed some classrooms of a Secondary School “Nautical Institute Gioeni - Trabia” in Palermo (Italy), which was planned and built during the mid twentieth century. In details the research regarded some classrooms of the Institute, meaningful for their exposure. They were analyzed in some particular periods, with the best or the worst conditions related to the quantity and quality of natural lighting system. In the following Fig. 1 there is a photo of the main front of the institute.

Figure 1. South front of the Nautical Institute “Gioeni – Trabia” in Palermo.

4. METODOLOGY

In order to obtain to a reliable and objective evaluation of the light microclimate, it was necessary a comparison of some parameters and the control of different data acquired by different instruments and methods.

After a careful analysis of rooms, in order to construct a simulation of the solar incidence on the building, also considering the context, we thought appropriate to go on the data acquisition using both a traditional methodology and a experimental one. In this way we have the reliability of the data and, in the same time, the validating and simultaneous control.

Then we specified the difficulty level of the visual tasks (reading, writing, reading the blackboard from the desks, writing on the blackboard, walking among the desks), the *task mapping,* listing of the lighting system devices. The survey, carried out in December, during the lesson hours, underlined a constant overlight level uneven with the prescription of Reference System of Norms.

Also the task-area is used in order to analyze the visual tasks that students will do on the blackboard. In details, the survey methodology has been carried out utilizing preventive simulations about the sun path and the relationship between sun and building by the software Ecotect® v 5.50 by Square-1.

During this step, special attention has been given to the main building, overlooking to one of the main roads of Palermo, where there are a lot of classrooms arranged on 5 levels. The first step carried out was the study of the shadowing of the front of the building on the 21st March, 21st May, 21st September, 21st December, from 8:00 to 18:00, the period during which the school is open and fully functional. In the following Fig. 2, there is an image of this simulation, in order to carry out preliminary screening on the classrooms which are object of the survey.

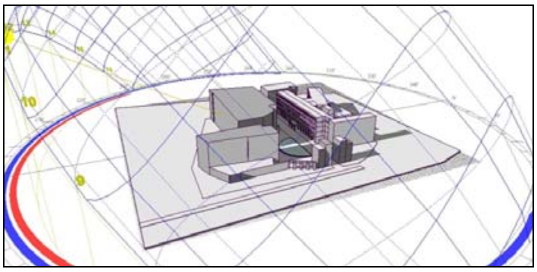

Figure 2. Simulation on 21st Decembers at 12:00 on the areas in shadow and sunned on the South faced of the building.

Successively, some measures on the field have been carried out by the use of a Minolta luxmeter-colorimeter, model CL-200 and of an LS-110 model of the same manufacturer.

This survey has allowed to draft a classification of the classrooms in “critical conditions” from the point of view of the luminous microclimate supporting the choice of the more meaningful rooms to the aims of the analysis.

Another simulation was about the calculation of the *Daylight Factor* and the *Daylight Level* on all the floors of the building exposed to South [10]. A chromatic map was made in order to define the levels and the quality of the lighting of the spaces. In the following Fig. 3, there is an image of the *Daylight Analysis* with the following input data:

- *Calculation type*: *Natural Light Level and Daylight Factor & Levels;*
- *Calculate Over: Analysis Grid;*
- *Design Sky Luminance: 6 000 lux;*
- *Sky Conditions: Overcast;*
- *General Settings: High;*
- *Window Cleanliness: Dirty (0.75).*

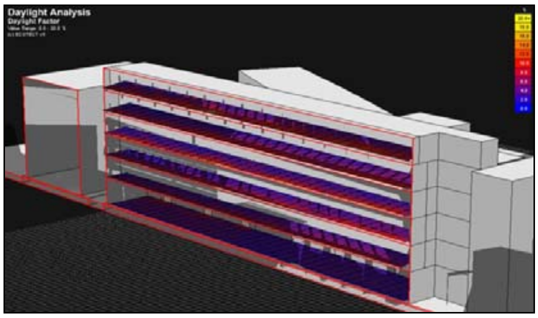

Figure 3. Daylight Factor mapping (%).

The phase of construction and study of the building has allowed us to understand which classrooms were disadvantaged considering visual comfort.

In particular:

- N.1 classroom situated in a marginal position at the 2nd level, having an external wall without windows, the wall facing the main road has four 1,50 x 1.50 square windows; occupation \ density: 30 persons;
- N.1 classroom situated in a central position at the 3rd level, facing the main road with three 1,50 x1,50 square windows; occupation \ density: 18 persons;
- N.1 classroom situated at the 4th level, with two blind walls. The wall facing the main road has three 1,50 x 1.50 square windows; occupation \ density: 18 persons.

Briefly, this article deals with the survey carried out in the classroom situated at the 2nd level because it is sufficiently representative of the methodology used.

The following Fig. 4 shows an overlap of the maps at the different levels, illustrating the right locations, while in Fig. 5 there is an inner sight of the classroom.

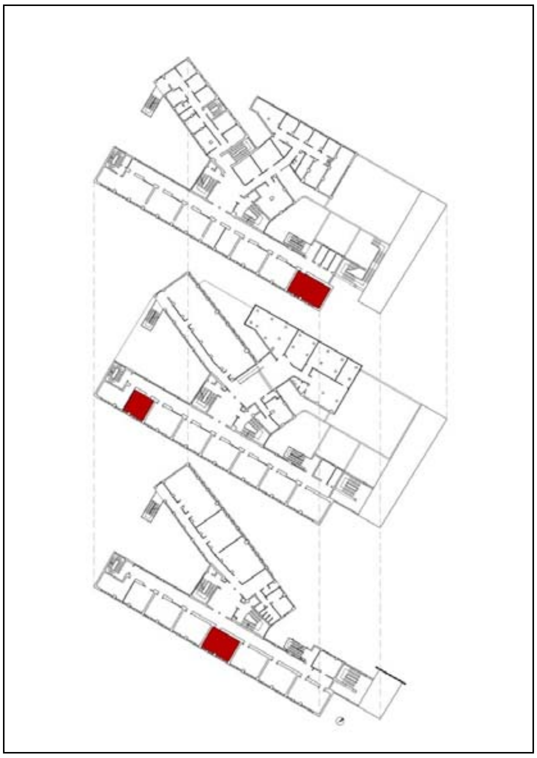

Figure 4. Location of the classrooms at the different levels, object of the survey.

Figure 5. Inner sight of the classroom object of the survey.

The indoor classroom occupied by the students has been divided in *Cluster* and *Frame* [11] in order to discover both the positions occupied by the students and to identify the points on which the values of Daylight Factor (%) can be simulated.

Such portions of space are rectangles, with defined dimensions, inside of which there are the students' desks. Inside of the desks' spaces there is also the one occupied by students during their reading-writing visual tasks. Fig. 6 and 7 shows the above mentioned areas and the relative points of measure.

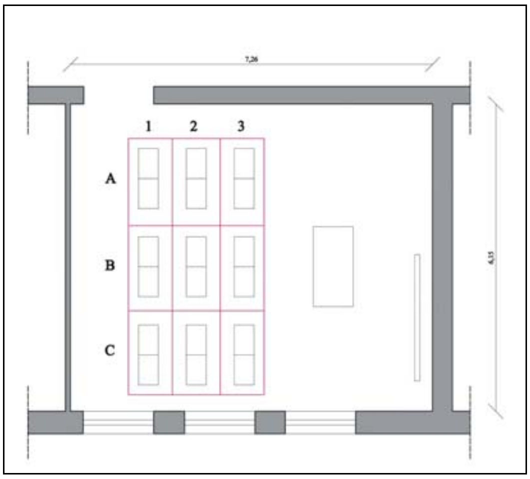

Figure 6. Area of the classroom with the *cluster* and *frame*, object of study.

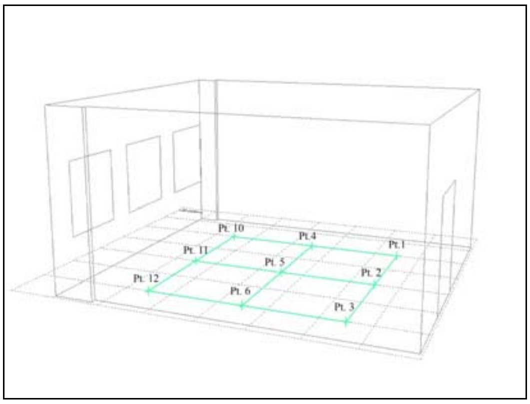

Figure 7. Points of measure (Point test) indoor classroom object of study.

To confirm the study model, has been researched, in the same conditions, the time frame in witch the classrooms are used trough dynamic simulations.

The dynamic simulations are plausible considering the negligible floating index, with the measured data. Below, in Fig. 8, is showed the float, and the trend of lighting levels (lx) is showed.

In particular the time frame is investigated in two Test Points: Pt1 (measured Test Point), Pts1 (simulated Test Point) Pt4 (measured Test Point), Pts4 (simulated Test Point) [12].

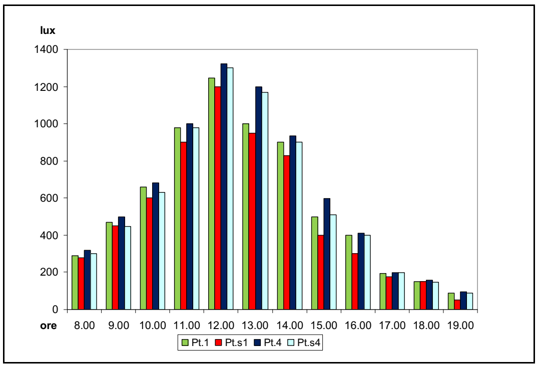

Figure 8. Floating analysis between measured Test Point (Pt. n) and simulated Test Point (Pt.sn).

In Table 1, the simulated values of Daylight Factor are quoted. It has been calculated the value of the average DF (%) that is 4,1%, qualitatively acceptable but the comparison with the light values of E (lux) quoted in the diagram of Fig. 9, has found excessively high values to cause discomfort in the development of the visual task.

Table 1. Simulation of the values of DF (%).

Pt	DF(%)
1	2,3
2	2,8
3	3,2
4	4,3
5	5,1
6	4,9
7	6,0
8	6,3
9	7,5
Average	4,7

A part of the study concerning the lighting levels on the desks, is shown in Fig. 8 and 9 below. In particular, it has been evaluated the evolution of the lighting levels in March 21, September 21, May 21, December 21.

The referred time frame goes from 8:00 am to 18:00 pm, time slot in which the school is occupied for lessons and afternoon courses. It seems appropriate, considering the results obtained, to indicate the optimal range (red band) for the proper performance of visual tasks in schools prescribed by the UNI EN 12464 (300 lux) and UNI 10840 (300 lux high school, 500 lux evening courses for adults).

It has also been simulated, on the desk surface, the value of Daylight Factor for each hour, investigated by linking it to the values of outdoor lighting E (LUX) provided by the control units for detection of DREAM and for the year 2005 [13]. These data are related to measurements carried out every 20 minutes, while those used concerns the hourly average.

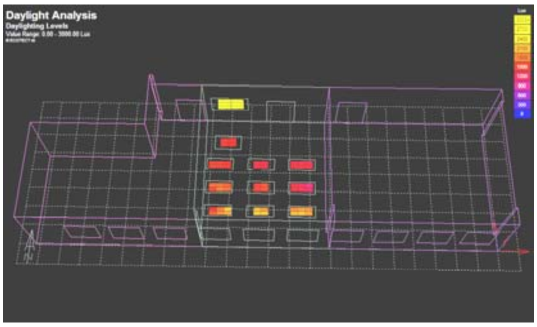

Figure 9. Simulated *Daylighting Level* on the desks.

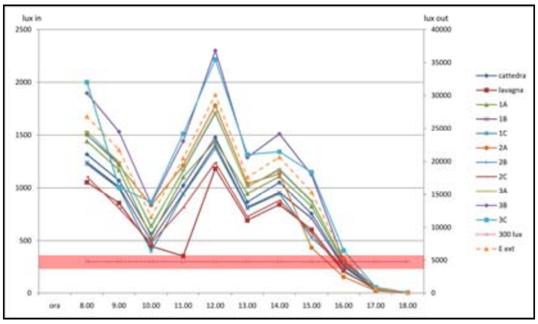

Figure 10. Measured *Daylighting Level* inside each frame.

5. THE ADAPTIVE APPROACH

For the adaptive approach has been developed a special questionnaire submitted to pupils in each of the classes investigated. The questionnaire, originally developed by researchers of Turin Polytechnic (Italy) [14], has been revised and adapted for the specific conditions of the classrooms studied. First of all, a careful analysis on each classroom has been done in order to realize a map to be attached to a multiple choice questionnaire.

We asked each of the students to indicate, on the map provided, the location they usually have during the lessons.

The subjective analysis was carried out in order to reveal the level of satisfaction by the school users.

The questionnaire is divided into four parts:

- presence of eyesight diseases (astigmatism, myopia)
- frequency of screens use related to the difficulties to perform visual tasks (assessed both in the case of natural and artificial light),

- subjective evaluation of the difficulties in performing visual tasks
- satisfaction on taking control of all system shielding and plant.

5.1 Questions of the submitted test

1. Do you have any visual disorders (myopia, astigmatism, etc ...)?
2. How do you evaluate the amount of light on the blackboard?
3. How do you evaluate the amount of light on your desk? (insufficient …too much)?
4. Are there sometimes too much light on your desk (difficulty to read your book)?
5. What do you think about the following light sources: windows – light systems in the classroom according to your visual discomfort?
6. What do you think about the light distribution in the classroom (very uneven - very uniform)?
7. How important do you consider the possibility to control the lighting environment?
8. How often do you use the curtains to shield the light from the windows?
9. Are you satisfied how you see what the teacher writes on the blackboard?
10. During the year are you disturbed by the excessive brightness of glass surfaces?
11. During the year is it necessary to use the artificial light?
12. In your classroom can you:
    - control the natural light and the artificial one?
    - control the On and Off of the artificial lighting system?
    - control the light radiation through curtains or shades?
    - control the darkness of the room during the screening of a video?

5.2 Processing of the collected data

For the case reported in this article, the questionnaire was submitted on May 28, 2008, at 9:00.

The next stage of data processing has been obtained through a scoring [15] system of each parts of the questionnaire. We organized the output of data using a chromatic system based upon three colors and giving a value according to the predicted quality. The whole *scoring* system is due to the combination of the results of each questions. To a given score is linked an explanation about the situation of the visual distress risk. The overall scoring system is a combination of the results of several parts, each scoring total wins is an explanation of the associated risk of visual stress situation [16]. It is clear that students have considerable difficulty in performing visual tasks, especially those who occupy positions close to glass surfaces, due to frequent glaring, and confirming the data obtained through simulation and the questionnaire results. In the following Fig. 11, there is the mapping of the answers to the question “6” *What do you think about the light distribution in the classroom?*, while in the next Fig. 12 there is a short summary of the results obtained for each cluster studied.

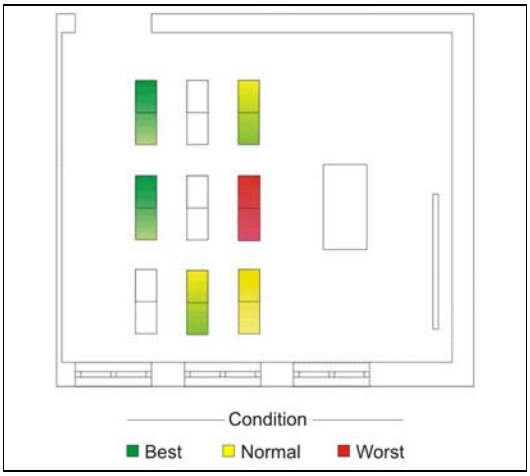

Figure 11. Colour mapping obtained by the interpretation of question “6” answered

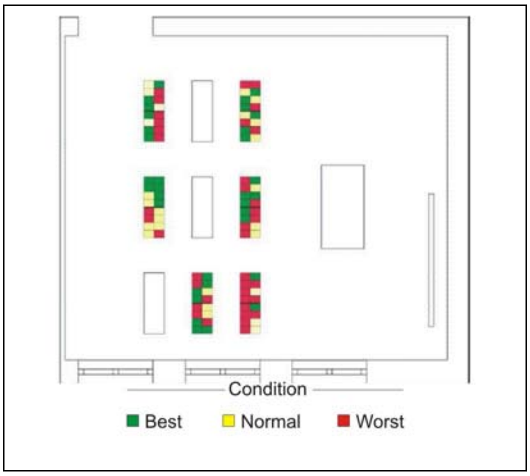

Figure 12. Whole colour mapping on all questions

6. CONCLUSIONS

The methodology shown here, compared with the traditional methodology about the investigation on the light microclimate of an environment, made of only instrumental measurements, shows a more oriented approach to user satisfaction. Within the framework of the welfare and of the subject comfort connected to the microclimate conditions inside an environment, it is an established practice to integrate different methodologies, including the traditional static model, the adaptive model and the measurements of the main characteristic greatness.

The results of this study shows clearly that the wide availability of natural light, if not properly controlled by different systems which allows an optimum use, is the cause of strong phenomena of over-lighting that lead to vision discomfort.

It seems appropriate, to complete the research, to give some project guide lines, based on passive systems to control the natural light in workplaces.

In particular, you can find in specific literature some solutions that can be used during the design and restructuring steps. Between the possible solutions, applicable to the front of the building, we suggest two *horizontal strips* for the screening and placement of a 45 cm *light-shelves*.

These project proposals have been applied to the study case, simulating the performance levels in terms of lighting and daylight factor and they gave the following results.

With the horizontal placement of the strips we have a fragmentation of light and the value of Daylight Factor (%) decreases significantly obtaining some optimal values.

With the simulations, we can note that only the desks far from the window have benefit, while the desks near the window have a worsening.

Instead, with the placement of the light shelf, despite the levels of Daylight Factor (%) are approximately equal to those of actual condition, we can note a significant increase in the quality of lighting microclimate due to the uniformity of values.

In the following Fig. 13-15 there are the simulations of the DF levels and the comparison chart in which there is the change in value of DF (%) in relation to the distance from the glass surface. The trendline (linear) is reported for each of its configurations.

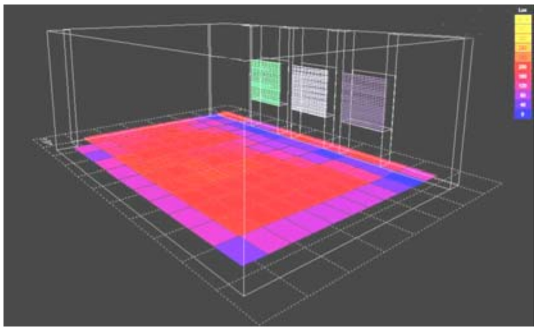

Figure 13. Daylight Factor (DF%) simulated (December 21) with horizontal strips on windows.

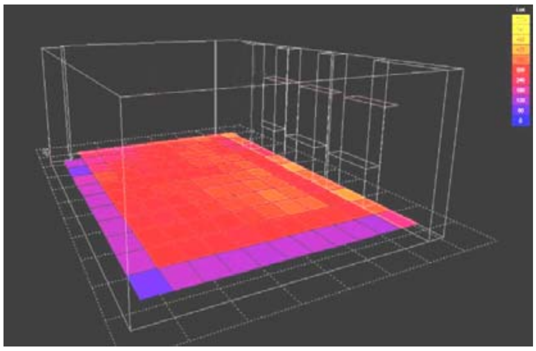

Figure 14. Daylight Factor (DF%) simulated (December 21) with light-shelf on windows

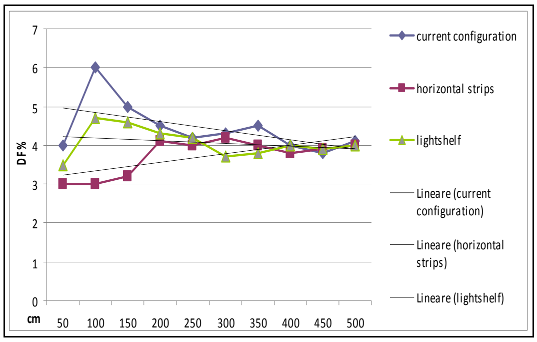

Figure 15. Comparison between the proposed configurations

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