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Questions of graphic standardization in the teaching of Computer Aided Architectural Drawing.

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Abstract — **In this paper I want to present some considerations about graphic standards applied to CAD drawing and object of teaching in I Faculty of Architecture of Polytechnic of Turin. They concern both the specific formats of CAD's software (as the layers, the file naming…) and the relationship between Italian and European Graphic Standards (UNI and ISO) and CAD systems of representation about the line thicknesses, the text styles and dimensions, the scales, the material renditions…**

Aim of the research is to introduce the students of the first year of Architecture to the problems of drawing standards applied to the architectural design.

With regard to layer standards were analyzed in particular the "AIA CAD Layer Guidelines" related to the "University of Kansas Layer Standard". Starting from these two sources I have synthesized the format of an architectural scale drawing (1:200-1:50) in a limited number of layers, useful for beginners both in architecture and in CAD.

With regard, for example, to material renditions, were compared the "Basic conventions for representing areas on cuts and sections", proposed by UNI ISO, with the hatches offered by software, and were selected and customized the most useful in architectural drawing.

The results of this work, partial and continuously updated, consist of a series of proposals oriented to optimize the students' method of CAD drawing, complying with the existent graphic standards.

Key Words — **CAD, Graphic standards, Teaching, Architectural design drawing.**

I. Introduction

1st Degree in Architecture Science of Polytechnic of Turin promotes the centrality of architectural and urban design in its curriculum.

Design means both dialogue between knowledge, for solving operative problems according to the polytechnic model, and check of knowledge reached starting from real occasions.

For this reasons, laboratories activities are very important in this course. The main activity is planning, pointing on various aspects, scales and integration of different topics.

There are three different labs during the years: Architecture - Town Planning; Architecture - Restoration; Architecture - Technology. Every lab engages almost half year of study.

The activity of labs is founded on the contribute of different disciplines, that change every year, like architectural design, architectural and CAD drawing, architectural and urban survey, architectural technology, structure, history of architecture, real estate evaluation, technical physic, town planning.

In particular the disciplines of Representation are present in each of the labs.

Starting from the first year of study, and therefore from the first lab, is strictly necessary that students master the language of drawing to communicate architectural ideas.

The following considerations are referred to the part of the teaching dedicated to the architectural design drawing realized by CAD.

In particular are presented some proposals about graphic standards applied to CAD drawing.

They concern both the specific formats of CAD's software (as the layers, the file naming…) and the relationship between

Italian and European Graphic Standards (UNI and ISO) and CAD systems of representation about the line thicknesses, the text styles and dimensions, the scales, the material renditions…

Aim of the research is to introduce the students of the first year of Architecture to the problems of drawing standards applied to the architectural design.

In a phrase, the work consists of a scientific research on graphic standards, both in architectural drawing and computer aided drawing, applied to a didactic experience.

This practice implies to simplify, to adapt, and to implement the data drawn out from the sources.

II. Materials and Methods

In Italy, reference sources, that develop the problem of architectural graphic conventions, are UNI standards about technical drawings.

In 2006, these standards, born in the ambit of mechanical drawing, were collected in two new books [1] dedicated to building design representation.

This renovated attention to architectural design drawing implies major attention to the specificity of this kind of drawing about topics like line-types and line-weights, representation of materials, dimensioning, use of signs and symbols… Moreover the norms have been enriched with a lot of drawn examples, related to architectural elements and details.

Some references, limited to terminology, are about CAD drawing.

This represents a limit for the teaching of technical architectural drawing because since the beginning of the course it is applied to CAD.

Reference sources about CAD standards are: ISO 13567[2], on "Organization and naming of layers for CAD", AEC Standards [3], an adaptation of BS1192 based on Uniclass, on "Line thickness", "Text and dimension", "Scales", "File Naming Standards", "Architectural layers", AIA Task Force on CAD Layer Guidelines [4], on "File name" and "Layer name", USNCS [5], that includes AIA CAD Layer Guidelines, Uniform Drawing System, and Plotting Guidelines.

Other interesting studies, basis of the research, have been carried out by CLG [6] (that provided modifications to AIA CAD Layer Guidelines concerning line-type and color specifier), by University of Kansas [7] (that proposes Architectural Layer Standards starting from the works of AIA and NCS), by a researchers group convened by Bo-Christer Björk [8] (that presented Swedish and Finnish implementation experiences of layering system based on ISO 13567).

The limits of the application of the results of these works and researches to the didactic activities consist of the complexity of the proposals, thought for users able both in building design and in CAD drawing.

Finally CAD systems are both tools for design drawing and sources of drawing standards, offering some predefined templates of line-types, fonts, hatches, dimensions, symbols, sheets, layouts…

In the didactic experience AutoCAD 2008 is used like a basic software for 2-D and 3-D modeling, because it forces the students to draw with geometric primitives, like lines, surfaces, volumes, and to attribute to each of them the meaning of a concrete element of the architectural project.

It is also a useful approach to computer aided design because it allows the students to represent the shape in their mind with a geometric 3-D model. The following step of their learning may be going on to BIM software.

In 1st year laboratory, experiences reproduce – with some necessary simplifications and differences – the architectural design real process, starting to deal with the high level of complexity typical in the human – built environment system. The students, about sixty in each laboratory, work on a wide area, selected by the teachers in small towns near Turin, and project in large groups at urban scale, in a couple at architectural scale. Each group have to project in a parcel of the area according to the town plan.

The didactic activity of computer aided drawing simulates the goals of a overall company-wide IT strategy: to facilitate cooperation between students within the class, to improve information exchange between all parties involved in the project, to enable the re-use of proven good solutions in new projects.

For this reason, a common information structure, obtained by the standardization of CAD drawing, is strictly necessary.

In the following paragraphs are developed as examples the themes of layer standards and of material rendition.

A. Layer Standards

Layer standardization involves some questions, like the design methods, the organization of work, the formats used into the file, the characteristics of project model (2 or 3D), the discipline field, the scale or the scales of drawing, the requirements of plotting output.

Moreover it involves some questions related to technical drawings graphic standards like line-types and line-weights.

Increasingly CAD-systems are used not as digital drawing-boards, but for managing integrated 2-D (or at best 3-D) models of a complete building. A system such as AutoCAD makes a clear distinction between model-space (containing the model of the building in world coordinates) and paper-space (containing output from such models in drawing sheet coordinates). As a consequence a prerequisite for efficient data transfer and sharing is that the information in such models must be structured and partitioned in standardized ways. In current CAD-practice quite elaborate layering schemes, provide the dominating method used to achieve this end.

In layering systems each drawing primitive is assigned to some layer. The user can then interactively decide which layers to show actively on the screen or to output on a plotter.

In 2-D CAD, the CAD model is used to store one or several

projections of a building, rather than a full 3-D model. The three main projections (plan, section, and elevation) can be split into independent models, but for dimensional co-ordination purposes it can also be useful to store them in the same model. In such a case, it is useful to be able to use layering for splitting up the model into these categories.

These different representations of the same parts share some properties, such as location points. In particular output drawings only one alternative is usually shown, but in the full model it is useful if all of these can be included in the same model, rather than having non-integrated separate models for drawings at different scales.

The layering facility can be used to facilitate the storing of presentations related to different scales in the same model, and such a classification can be included in the standard. Since the scales used in construction documentation are well known (and have in fact been standardised by ISO) it has been possible to prescribe the scale alternatives included in the layer standard.

To apply these observations to the teaching needs to reduce the number of layer and to define, without misunderstanding, the content of each layer.

Based on the above mentioned sources, has been synthesized the format of an architectural scale drawing (1:200- 1:50) in a limited number of layers, useful for beginners both in architecture and in CAD.

The present full layer codes, resulting from the ISO and from the AEC standards, are not easily comprehensible. AIA standards are easier readable, but the limited knowledge about Architecture of 1st year students suggests to simplify the layer naming, writing the full name of each element.

The layer name format is organized as a hierarchy with two mandatory data fields, showing the discipline and the object (an element of building, a kind of annotation, an architectural symbol…, for example, A-WALL). Another optional field specifies possible characteristics of objects. The layer name is provided with full explanation to the layer contents.

In the resulting applications the structuring of information in layers has been combined with a model-oriented approach to 2D CAD. Documents are produced using file references with a model space/ paper space system. The number of layers used in a project are not nearly as many as the standard allows. Standard layer lists, which are loaded with every new CAD file, contain about forty layers. These are the layers found to be currently used in order to control visibility on drawings and on screen.

To format AutoCAD layers implies to attribute a colour and a line-type to each of them.

Using a colour-dependent plot style an object's colour determines how it is plotted. In this way each layer can be

TABLE I

2D architectural drawings (plans, sections, elevations - scale 1:200, 1:100, 1:50) layer standards

layer name	description	color	linetype	lineweight	plot	plot color	plot width1	plot width2
A-FOUNDATIONS	foundations	red	continuous	default	on	black	0.18	0.1
A-FOUNDATIONS-SECT	foundations in section	white	continuous	default	on	black	0.35	0.2
A-FLOORS	floors, slabs	red	continuous	default	on	black	0.18	0.1
A-FLOORS-SECT	floors, slabs in section	white	continuous	default	on	black	0.35	0.2
A-STAIRS	stairs (incl. balaustrades), ramps	red	continuous	default	on	black	0.18	0.1
A-STAIRS-SECT	stairs and ramps in section	white	continuous	default	on	black	0.35	0.2
A-ROOFS	roofs	red	continuous	default	on	black	0.18	0.1
A-ROOFS-SECT	roofs in section	white	continuous	default	on	black	0.35	0.2
A-WALLS	walls	red	continuous	default	on	black	0.18	0.1
A-WALLS-SECT	walls in section	white	continuous	default	on	black	0.35	0.2
A-COLUMNS	structural frame, columns, beams, bracing	red	continuous	default	on	black	0.18	0.1
A-COLUMNS-SECT	structural frame, columns, beams, bracing in section	white	continuous	default	on	black	0.35	0.2
A-WINDOWS	windows	blue	continuous	default	on	black	0.18	0.1
A-DOORS	doors	blue	continuous	default	on	black	0.18	0.1
A-FURNITURES-FREE	freestanding furnitures, equipments,	9	continuous	default	on	black	0.09	0.05
A-FURNITURES-FIXD	fixed furnitures, sanitary fittings	8	continuous	default	on	black	0.09	0.05
A-FITTINGS	fittings (external and internal)	8	continuous	default	on	black	0.09	0.05
A-LIFTS	lifts	red	continuous	default	on	black	0.18	0.1
A-EXTSITE-WK	external site works	yellow	continuous	default	on	black	0.18	0.1
A-EXTSITE-FURN	furnitures/equipment of external site	8	continuous	default	on	black	0.09	0.05
A-SYMBOLS	symbols (door swing, stair arrows, north arrow, graphic scale)	cyan	continuous	default	on	black	0.09	0.05
A-AXIS	simmetry axis of doors, windows, columns	cyan	continuous	default	on	black	0.09	0.05
A-PLAN-CUT	plan cut	blue	dash-dot	default	on	black	0.18	0.1
A-ABOVE-PLANCUT	objects above the plan cut	yellow	hidden	default	on	black	0.18	0.1
A-GROUNDLINE	ground line	green	continuous	default	on	black	0.7	0.4
A-CARS	cars	cyan	continuous	default	on	black	0.09	0.05
A-PEOPLE	people	cyan	continuous	default	on	black	0.09	0.05
A-TREES	trees	cyan	continuous	default	on	black	0.09	0.05
A-XREF	external reference (Xref)	cyan	continuous	default	on	black	0.09	0.05
A-IMAGE-REF	raster image reference	cyan	continuous	default	on	black	0.09	0.05
A-HATCHES-SECT	hatches in section (materials cut by sections)	9	continuous	default	on	black	0.09	0.05
A-HATCHES-ELEV	hatches in elevation (materials textures)	9	continuous	default	on	black	0.09	0.05
A-FLOOR-PATT	floor patterns, pavements and landscaping (ground, etc.)	9	continuous	default	on	black	0.09	0.05
A-TEXTS	texts	blue	continuous	default	on	black	0.18	0.1
A-DIMENSIONS	dimensions	magenta	continuous	default	on	black	0.09	0.05
A-ELEVATIONMARK	elevation markers	magenta	continuous	default	on	black	0.09	0.05
A- CONSTRUCTION	construction lines	red	continuous	default	off	black	no plot	no plot
A-PS-SHEET	sheet settings (paper space)	white	continuous	default	on	black	0.35	0.2
A-PS-VIEWPORT	viewports (paper space)	cyan	continuous	default	on	black	0.18	0.1

plotted with a particular line-weight [9].

As UNI ISO 128-23 [10] recommends, in a construction drawings have to be used three widths of line: fine, wide, extra-wide. These widths have to be in 1:2:4 ratio, to be distinguished. Although AutoCAD and plotting devices permit to set countless widths of line, in a technical drawing is preferable to select a limited number of them.

Thus the choice of layer's colour may be reduced to four or five.

On the other hand it is necessary to consider the chance to attribute to a colour, in AutoCAD model space, a meaning (for example: sectioned entities), or a reference to an element of building (for example: stairs, windows, etc.), or a reference to a subject of drawing (for example: dimensions, symbols).

In the didactic proposal it is suggested to use 1 to 9 basic colours to be printed in black with four different widths (see Table I).

B. Material representation

UNI 3972/1981 [11] and UNI ISO 128-50 [12] rule the materials representation in sectioned areas. The standardized hatches represent the main building materials through a symbolic pattern. Some architectural handbooks [13] suggest hatches representing other kinds of material in sectioned areas. The same sources display a series of proposals for material rendition in elevation, characterized by a iconic pattern.

In a 2-D architectural drawing (plans and sections), at 1:200 or 1:100 scale, it isn't recommendable to use hatches to distinguish materials. It may be only whenever it is necessary to emphasize an aspect of the project (for example the structural system). On the contrary, at the same scale it is necessary to use patterns to render materials in elevation.

AutoCAD offers some predefined hatches representing building materials in section and in elevation. Some of them, related to section drawings, are referred to ANSI ad JIS Standards, others represent patterns for specific materials in elevation (the prefix AR- refers them to the architectural field), others may be useful to designate different materials, referred not exclusively to the architectural field (see Table II).

In the didactic activity is prescribed the application of standardized hatches in plan and section and is suggested some references about materials rendition in elevation.

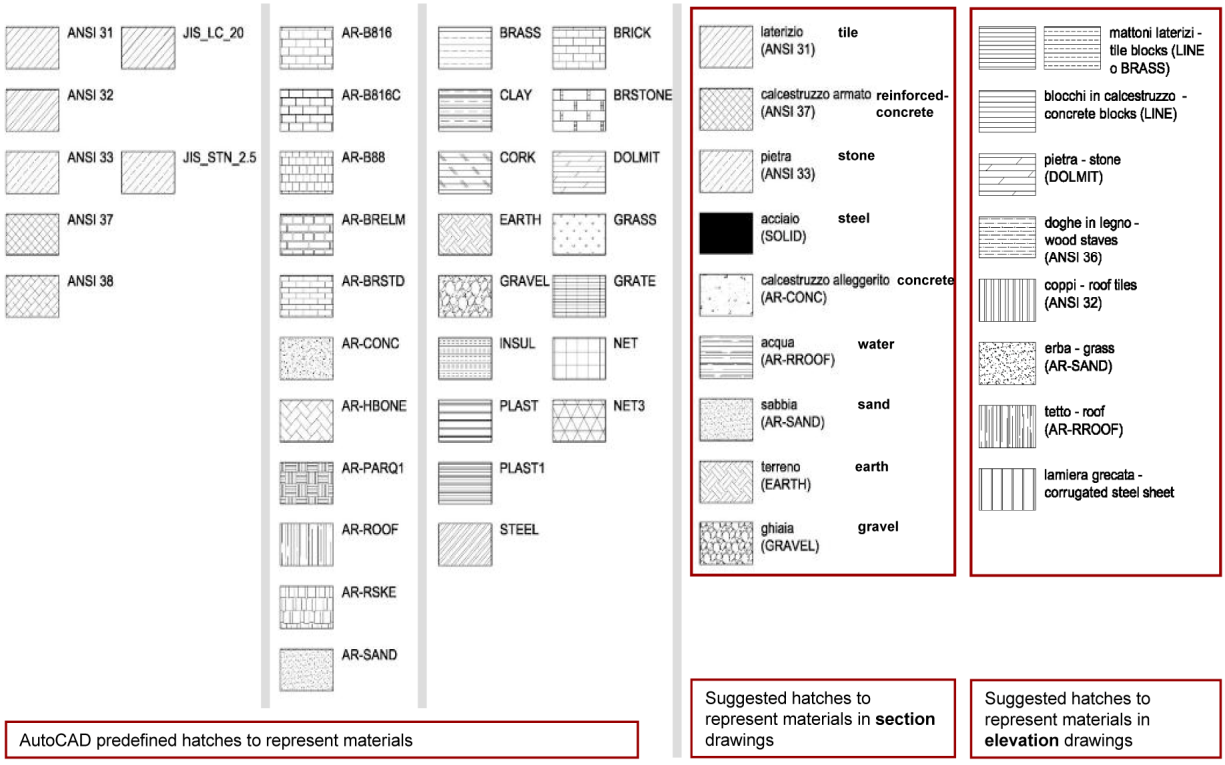
III. Results and Discussion

Obviously the research and its application to didactic activities have involved all the topics mentioned above.

UNI norms related to technical drawing are in their infancy regarding the application to Computer Aided Architectural Drawing, whereas they are quite advanced regarding specific graphic standards of architectural drawing.

The conformation of technical norms to CAD drawing requires revisions that consider specificities of CAD (for example: the lines thickness may be infinite, the lines may be

TABLE II



extremely thin).

Regarding to the topics above developed it is possible to underline some limits and values of the didactic proposal.

Limits regarding the didactic proposal for layer standards are the necessary simplification of layers name and the reduction of their number, values are to accustom the students working like in a professional team that applies international standards.

Limits regarding the didactic proposal for materials representation are in the format of software CAD that provides predefined hatches (whose scale is unknown) and allows limited modifications thwarting the creation of customized patterns.

Some graphical examples show the results of the proposals in the didactic activity (see Fig. 1-2).

IV. Conclusion

This research needs continuous updating and implementations related to the sources and to the new releases of software CAD. If, as it is foreseeable, the passage from CAD to BIM in building design process will happen, it will be necessary to arrange the architectural graphic standards to a new method of project rather than representation.

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[3] AEC (UK), an adaptation of BS1192 based on Uniclass, published in 1997 in UK by the Construction Project Information Committee.

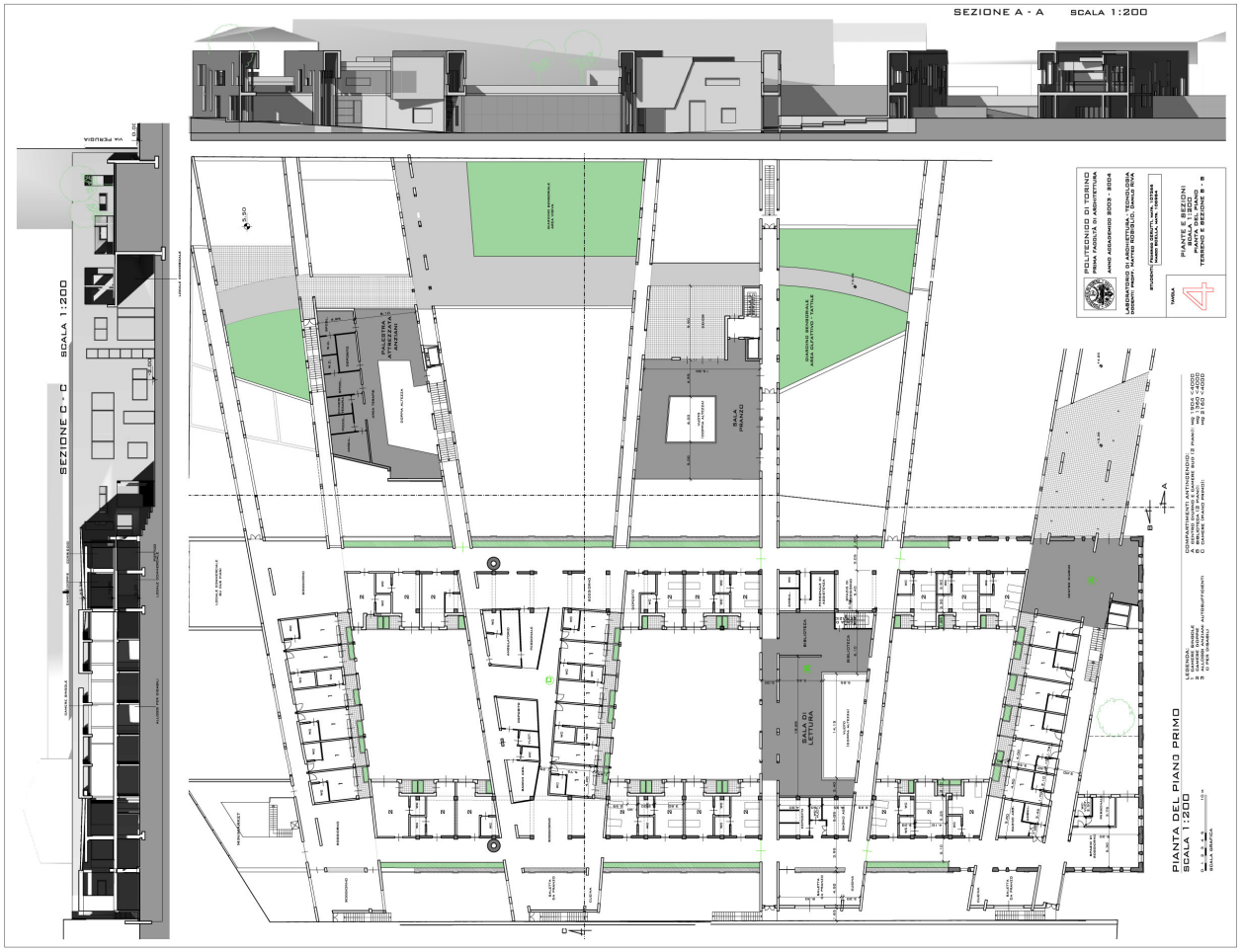

Fig. 1. Example of students 2-D CAD drawing. Plan, elevation, section, scale 1:200. Students Marco Boella and Federico Cerutti, professor Roberta Spallone.

[4] *CAD Guidelines*, Draft 6/11/96, Prepared by The AIA Task Force on CAD Layer Guidelines Michael Schley, AIA, Chairman Ken Sanders, Richard Buday, Dana C. Smith, David Takesuye.
[5] United States National CAD Standard, V4.0.
[6] CLG, *CAD Layer Guidelines*, 1996-2005.
[7] *University of Kansas Layer Standard*, 2006.
[8] B.C. Björk, K. Löwnertz, A. Kiviniemi, *ISO DIS 13567 - The Proposed International Standard for Structuring Layers in Computer Aided Building Design*, 1997.
[9] It is relatively easy to create different types of plots from the same CAD file, for example, using different scales, views, orientations, layer filters and pen/color settings.
[10] UNI ISO 128-23. July 2005. Lines on construction drawings.
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Fig. 2. Example of students 2-D CAD drawing. Plan, scale 1:50. Students Artan Gjoka and Davide Lantra, professor Roberta Spallone.