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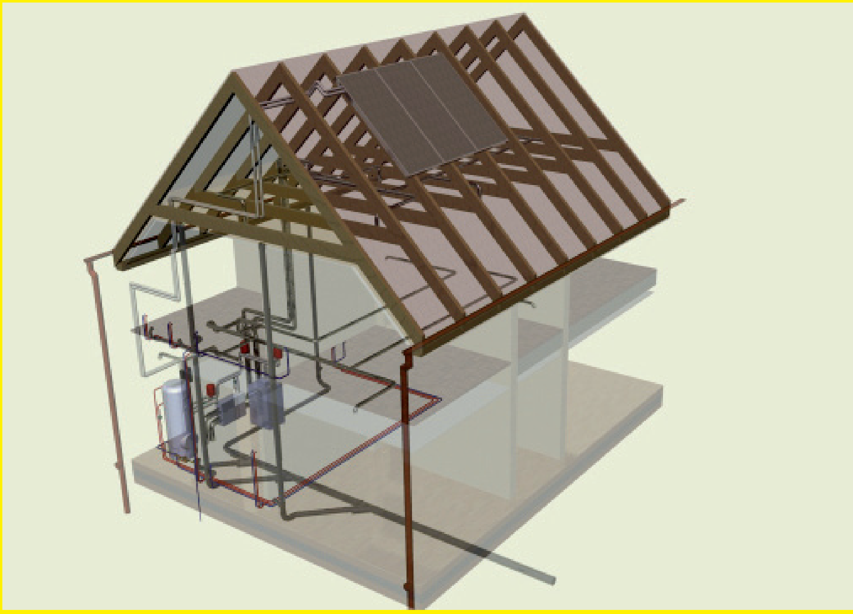

COMPUTER AIDED DESIGNING
3D Modeling of the Passive House

Zbigniew Suchorab, Grzegorz Łagód

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Introduction

Computer Aided Designing is one of the most important enhancements for the new generation engineers, especially in Environmental Engineering discipline. It is almost not possible to be a professional designer of the complicated sanitary systems who's working with tracing- or graph-paper and the technical pens, drawing complicated solutions and doing all necessary calculations with a small pocket calculator. Labor system in the modern design offices, their cooperation with the architects, investors and even contractors requires rapid reacting on the new changes and ideas within the realized investments. It obviously leads to the necessity of quick modifications of the implemented solutions or quick recalculation of the designed object parameters. In such a dynamic world, the traditional methods of designing become ineffective. Computer Aided Designing (CAD) is the current trend in modern engineering which is focused on helping the modern Environmental Engineer in quick reacting at ongoing changes of conditions of the accomplished tasks.

This book is devoted to one of the most important tools for Computer Aided Designing – AutoCAD. It is a graphical program used by almost each designing office. Whole description is based on AutoCAD 2012 edition and the special attention is put on modeling of three-dimensional objects. The elaboration presents the necessary features of AutoCAD based on modern "ribbon" interface. Also there are discussed the types of coordinates used for modeling in three-dimensional space, Global (GCS) and User Coordinate System (UCS) essential for working in 3D geometry, also helpful with typical 2D documentation.

As it was mentioned above, the major stress is put on 3D modeling and thus, this book presents the philosophy of 3D space projection, a review of three-dimensional objects and finally, as a completion, it presents an advanced tool of AutoCAD for graphical presentation – rendering.

All theoretical presentations are completed and confirmed with practical realization of an extraordinary engineering object – the passive house, which is especially interesting from the point of view of the Environmental Engineering domain. The last chapter of this monograph shows gradually the particular stages of passive house modeling, beginning from the technical data assumptions, projections of particular floors, construction of the funds, roof and other construction details, until the sanitary systems details, that make this building the passive object. Among the modeled installations there are ventilation system, cold and hot water supply system, sewage system, solar system, heat pumps and finally, rainwater system.

All modeling efforts are expressed in the form of rendering scenes which are comparable to photographs and maybe used in visualization for popularization of passive houses idea.

1 Working with AutoCAD 2012

1.1 AutoCAD 2012 interface

Working with AutoCAD 2012 and previous editions of described software relies on typing sequential commands which combinations enable formation of the expected documentation. Similarly to the older versions of this program, the access to the most available functions (often the most effective) is obtained by the commands typed using keyboard – e.g. “LINE”, “ARRAY”, “COPY”, “EXTRUDE” etc. The advanced users prefer this system of working with AutoCAD because it makes working faster – it does not require to take hands out of the keyboard by the operator. It is especially useful when the mostly used functions are personalized and each of them can be called by the keyboard shortcuts (*Autodesk, 2009a; Autodesk, 2009b*).

AuoCAD 2012 interface is based on so called “ribbon” system, where the mentioned ribbons are divided into particular Tabs (*McFarnland, 2009; Jaskulski, 2009; Wedding and Graham, 2009, Finkelstein 2011*) with Panels (Fig 1.1).

Fig. 1.1 presents the main window of AutoCAD 2012 in *2D Drafting & Annotation* mode.

Some of above mentioned elements of AutoCAD 2012 interface are typical and well known for most of users and will not be further described. Anyhow some of them are new for the ribbon interface of the application or are important from the point of view of 3D modeling and thus they will be widely presented in next chapters of this book.

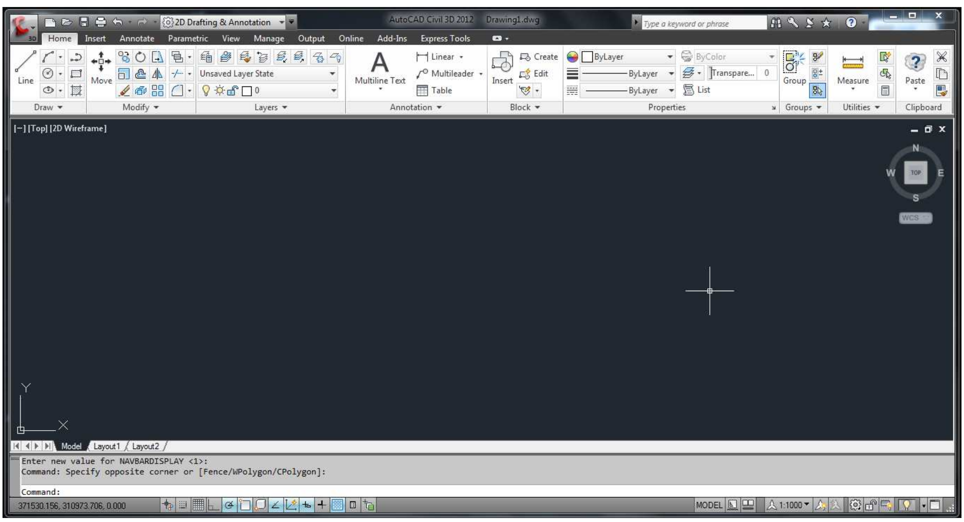

Fig. 1.1. AutoCAD 2012 interface *2D Drafting & Annotation*

AutoCAD 2012 enables switching between the different modes of interface:

- 2D mode (*2D Drafting & Annotation*) mostly applied for typical working with AutoCAD, giving full access to the major tools of the program (Fig. 1.1).
- 3D mode (*3D Modeling*), mostly applied for three-dimensional objects modeling (Fig. 1.2). The most important mode from the point of view of the following monograph and it is assumed that most of readers will use this mode, although it is not necessary.
- *Civil 3D*.
- *Planning and Analysis*.

Main elements of *3D Modeling* interface are (*Finkelstein, 2011*):

- Ribbon,
- Application button,
- Quick Access toolbar,
- Workspace drop-down list,
- Title bar,
- Help,
- Application Minimize, Maximize and Close buttons,
- Drawing Minimize, Maximize and Close buttons,
- ViewCube,
- UCS icon,
- Command line,
- Coordinate display,
- Layout tab,
- Drawing area,
- Status bar and Status bar menu,
- Crosshairs and Pickbox,
- Navigation bar,
- Clear screen button.

It must me underlined the fact that the classical interface (*AutoCAD Classic*), well known from the older versions of the application with the traditional Main Menu and Toolbars (Fig. 1.3) is no longer supported by the software producer and is not itemized here. Otherwise, sometimes it can be more convenient and intuitive for those with great experience in older versions of AutoCAD issues. From the point of view of the following book this approach is no longer recommended, anyhow the possibility of classic view implementation is presented over the world wide web, for example in the following thread of the popular CAD forum: *http://www.cadtutor.net/forum/showthread.php?58783-Classic-view-in-2012*.

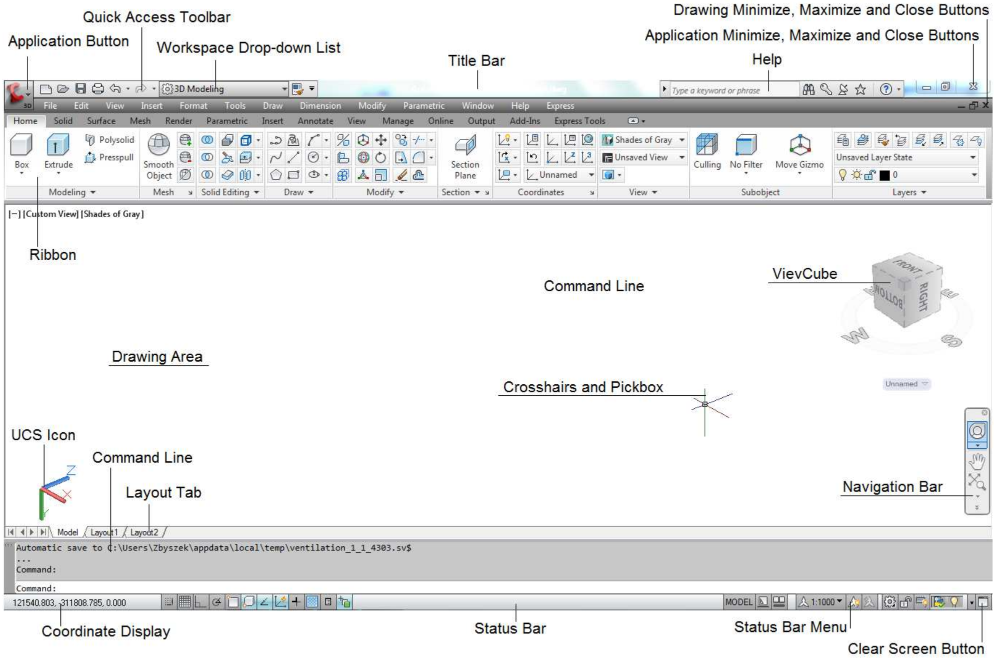

Fig. 1.2. AutoCAD 2012 interface *3D Modeling*

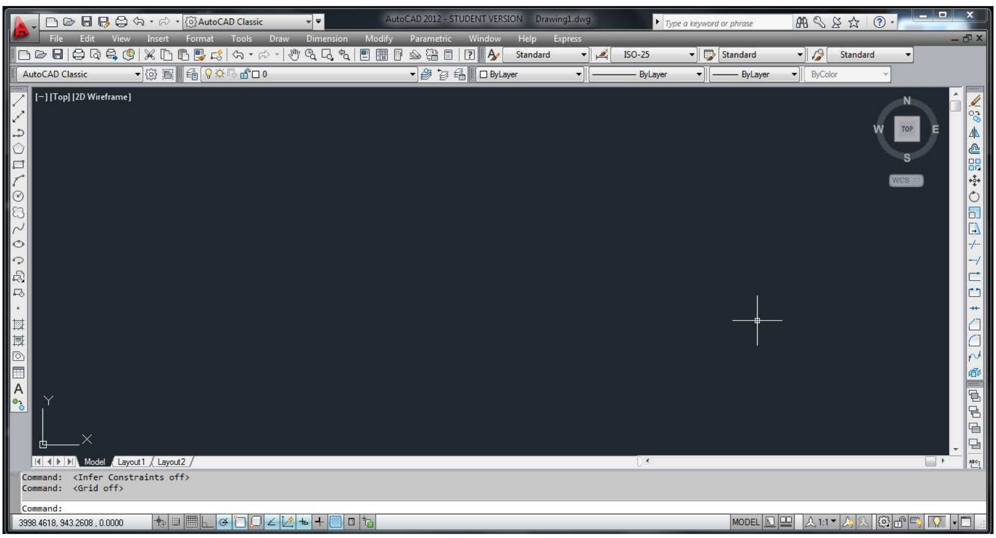

Fig. 1.3. AutoCAD 2012 interface *AutoCAD Classic*

1.2 *Working with AutoCAD 2012*

Working with AutoCAD 2012 may be difficult for the experienced users of the classical program interface. It requires the adaptation to the new application handling philosophy.

That's why automatic help system, offered by new interface is a big facility for each user and it seems very convenient to use the whole potential of it especially when working in ribbon interface for the first time. For example it is planned to use a very functional and frequently used in 3D modeling tool – BOX, generating a cube (one of the basic 3D solids) the user should find the described tool on a suitable Ribbon Panel and click the icon. If the icon is not clicked, helping label appears (Fig. 1.4) after a second or two. The label presents name of the command and its short description. If the cursor stops for about 2 seconds or more, an extended label will spread showing more detailed description of the following tool application – Fig. 1.5.

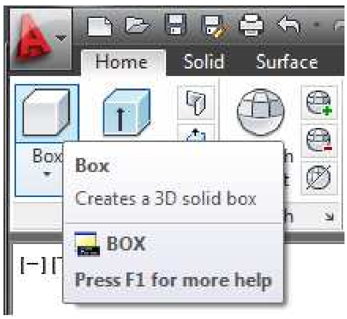

Fig. 1.4. Automatic help system in AutoCAD 2012

By clicking the chosen tool symbol (upper part of a button) it is possible to operate the command it refers to. In the above presented example a previously mentioned cube will be generated. Similarly to the older versions of AutoCAD the process of the object generating is a dialog between the program user and the application with particular sub-commands appearing in the Command Line, or on the Drawing Area when using the Dynamic Input mode.

Careful readers could have noticed, that the previously mentioned BOX icon is horizontally split into two parts. After the bottom part (with an arrow) is clicked, it extends showing other, similar tools. In that case there are buttons generating other primitive three-dimensional solids (Fig. 1.6). After the other tool (the cylinder, for example) is used, it becomes new actual main tool, visible at the described icon (Fig. 1.7). This AutoCAD 2012 interface solution makes working quicker and more efficient in case of many repetitions of this objects drawing.

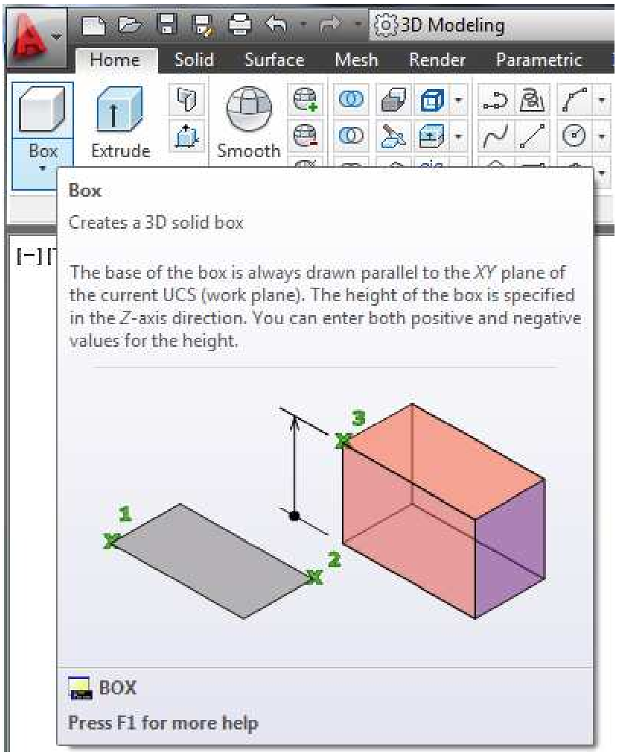

Fig. 1.5. Extended label with applied tool description

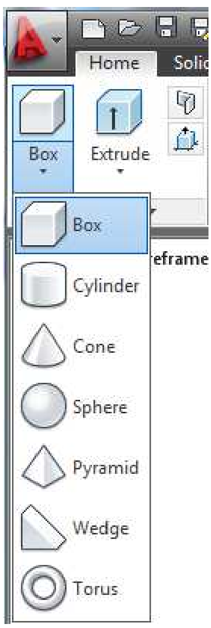

Fig. 1.6. Unfolded ribbon panel with solid primitives

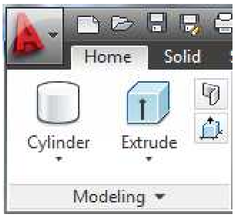

Fig. 1.7. Cylinder as a main tool of the 3D primitives icon

In the left Panel of the main *Home* Ribbon some particularly popular and mostly used tools are highlighted in the form of the greater buttons. Above discussed icon belongs to that group of commands. Of course, there are also not enrolling buttons among them, for example *Line* or *Move* in the main Tab of the *Home* Ribbon of the *2D Drafting & Annotation* interface mode (Fig. 1.8). Besides the above described, there are many tools represented by smaller icons with comparable functioning and thus they will not be more precisely discussed in this chapter.

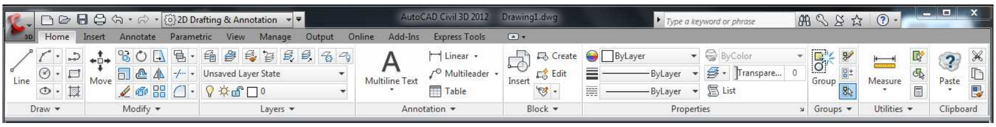

Fig. 1.8. *Home* Tab of *2D Drafting & Annotation* Ribbon

Within the particular Tab of the Ribbon all the buttons are put together into the suitable functioning groups, for example DRAW or MODIFY. Those groups are named Panels (Fig. 1.8, Fig. 1.9) At the Panels, there are presented only the essential tools. Access to rarely used tools relies on clicking the button below panel (with the small arrow) – Fig. 1.9.

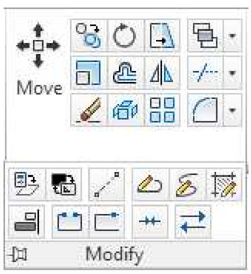

Fig. 1.9. Brought down *Modify* Panel

If the particular, advanced tools are often used by the particular user, the AutoCAD offers the possibility to lock them within the Drawing Area by clicking the pin symbol presented in Fig. 1.9 (left, bottom corner). Of course it is connected with the decrease of Drawing Area during modeling.

Additionally, it must be mentioned here, that AutoCAD 2012 interface gives the possibility to use different Ribbon styles:

Ribbon fully visible,

- *Minimize to Tabs* – Ribbon is hidden with the only Tabs visible. After the particular Tab is selected, full Ribbon appears. After the cursor leaves the Ribbon, it disappears again,
- *Minimize to Panel Titles* – Ribbon is hidden with Tabs and suitable Panel names visible. After the particular Panel is selected it fully unfolds. After the cursor leaves the Panel area, it disappears again,
- *Minimize to Panel Buttons* – Ribbon style similar to the above described – Ribbon is hidden with Tabs and suitable Panel buttons visible. After the particular Button is selected, Panel unfolds. After the cursor leaves the Panel area, it disappears again,

Change of Ribbon styles enables menu button at the right-hand end of the Panel titles. Its application enables effective increase of Drawing Area for designing or modeling which may especially useful during working in 3D environment using many viewports at small display.

1.3 Command Line Window

Command Line Window of AutoCAD 2012 is divided into:

- Command Line,
- History of Command Line.

The ability of efficient command handling, using Command Line is the essence of the professional AutoCAD use. As it was mentioned above, it is very important to know, that most of the AutoCAD tools, which are accessible from the level of the Ribbon or the Application Menu, can be called out in the Command Line. Of course, it requires the user to know these Commands names (Fig. 1.10) which are sometimes hard to remember, anyhow, such an approach may increase drawing efficiency. In this book, access to all functions will be presented at the level of Command Line and the Ribbon (if possible). In standard, Command Line Window is located in bottom part of Application Window. It can be even extended to external window (AutoCAD Text Window) by pressing F2 button (Fig. 1.11). Also it is possible to hide or unhide Command Line Window using the following buttons combination: CTRL+9, which seems unreasonable from the practical point of view. Command Line Window enables tracing the details of any document formation (history of the design development) or checking many important details of modeled objects like physical parameters, mass, centre of gravity etc.

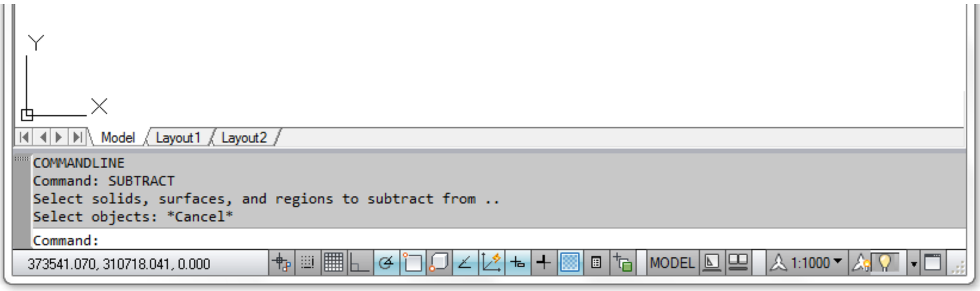

Fig. 1.10. Command Line of AutoCAD 2012

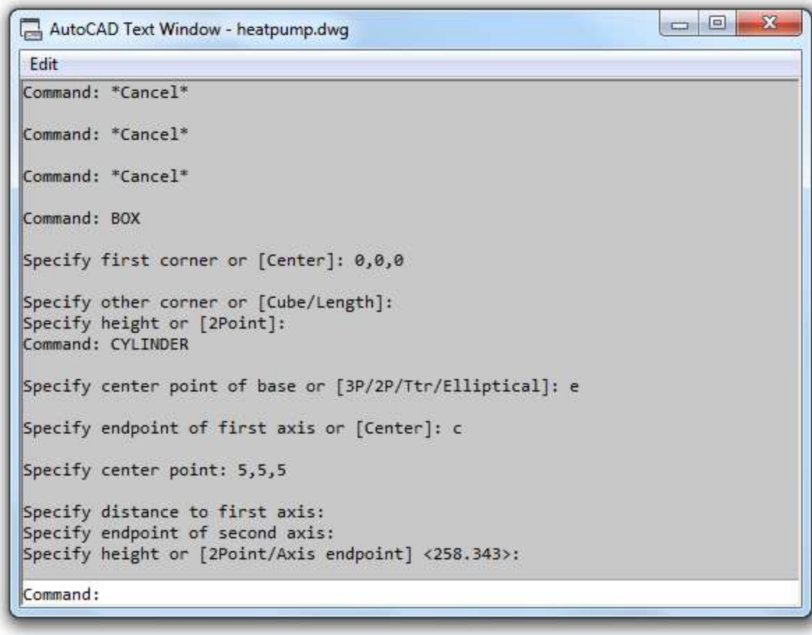

Fig. 1.11. Command Line in external dialog (AutoCAD Text Window)

When AutoCAD is ready to work the following prompt sign is visible:

Command:

After the command is typed, it ought to be confirmed with Enter or space button pressing. To make work more effective, shortcut system is used, for example LINE – L, EXTRUDE – EXT, REVOLVE – REV. More advanced users of AutoCAD often personalize their working environment, modifying the default shortcuts by editing the special text file with program parameters – *acad.pgp* (*External Command and Command Alias Definitions*) which can be found in the following location: *UserDataCache\Support*.

Drawing in AutoCAD is a sequence of dialogs between the system and the operator. After the particular command is typed (using Ribbon or the keyboard), a sequence of subcommands appears. These subcommands allow the execution of more complicated tasks in several steps. The example of such a sequence-given command is presented on Fig. 1.11.

AutoCAD interface in the latest versions enables Dynamic Input mode which enables Heads-Up Display (HUD) working. This means the possibility to focus on Drawing Area, without the necessity to observe the Command Line, which is traditionally positioned in the bottom part of the display. Particular stages of dialog with Dynamic Input interface are presented on the screen depending on context, close to the generated objects. Fig. 1.12 presents drawing a 3D object using Dynamic Input.

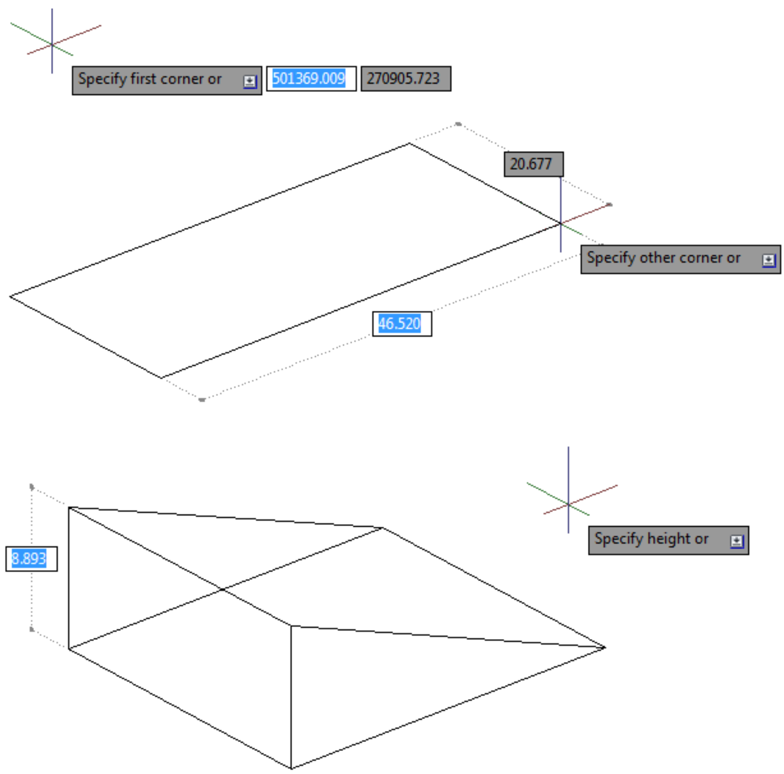

Fig. 1.12. Dynamic Input interface presentation on the example of solid primitive modeling

Many Commands offer various sub-options which means that during operating in Dynamic Input interface, Option List appears which enables to choose any required sub-command. Such an Option List is presented on Fig. 1.13.

Finally it must be mentioned here, that some experienced users may not be satisfied with the modern HUD interface. The possibility to turn off the Dynamic Input interface is available in Drafting Settings Window, Dynamic Input Tab.

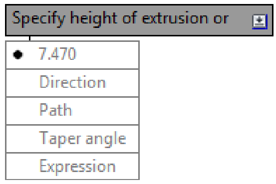

Fig. 1.13. Option List of EXTRUDE command in Dynamic Input interface

1.4 Object Properties and Layers

To keep the AutoCAD drawing in suitable structure and perfectly organized files it is recommended to manage the system of object properties. The most important among them are: layers, lineweight, linetypes and colors (*Munir, 2010; Wedding and Graham, 2009*). It is assumed that the reader of this book handles the basic system of layers and other properties during working with AutoCAD. Anyhow, it should be underlined that working in 3D particularly requires to use layers and other object properties. The most important property of each object is *Layer*, marked by the logical property *ByLayer*, which means that the described object property is suitable for particular layer. AutoCAD 2012 interface enables to change other, before mentioned parameters like Color, Lineweight or Linetype, anyhow it is not considered as a good practice or habit. It is considered as chaos generator in the elaborated documentation.

Access to the Layer Properties Manager is available from the Home Ribbon, Layers Panel and the first icon – *Layer Properies* (Fig. 1.14) or simply, typing the suitable command: *Layer*. Another possibility is to use *Menu Bar – Format – Layer*.

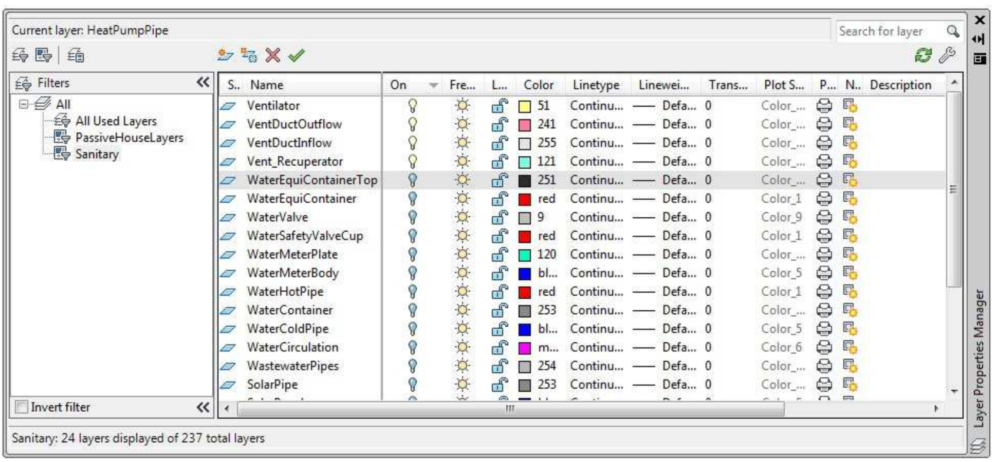

Fig. 1.14. Layer Properties Manager in AutoCAD 2012

Layer Properties Manager is a convenient tool for layers creation and management, which makes it one of the most important dialog windows in the whole AutoCAD 2012 interface.

Layer Properties Manager window is splited into two panels. The left one (*Filters*) is used for filtering and grouping the layers depending on their particular features. To create a new filter, *New Property Filter* button should be pressed which releases a new dialog window – *Layer Filter Properties*, where particular filters can be formed. Layer filter creation and management will not be furher described in this elaboration. Anyhow it ought to be underlined, that layer properties filter can be a very usefull manager especially in complicated developments. Another possibility for managing of the layers in a complicated design developments is to group them depending on their application. For that aim *New Group Filter* button should be used which enables formation any group filters. In previously mendioned Fig. 1.14 there can be found two group filters, which are separated into two types of layers: *PassiveHouseLayers* and *Sanitary* and were applied in the 3rd, practical part of this book.

Right panel of the *Layer Properties Manager* dialog window consists of list of the layers and their properties. Among them there are (*Finkelstein, 2011*):

- *Status* – shows if particular layer is used or unused, checkmark shows which layer is current,
- *Name* – the name of the layer,
- *On/Off* – turns the particular layers on and off during project development,
- *Thaw/Freez*e – thaws and freezes layers in the whole drawing, similarly to *On/Off* feature,
- *Lock/Unlock* – prevents locked layers from being changed, which makes them not possible to be modified,
- *Color* – enables to set the color of the particular layer using *Select Color* dialog window,
- *Linetype* – enables to set the linetype (continous, dashed, etc.) of the particular layer using *Select Linetype* dialog window,
- *Lineweight* – enables to set the lineweight of the particular layer using *Lineweight* dialog window,
- *Transparency* – enables to set the transparency of the objects of the particular layer. Avalaiable values are between 0 and 90,
- *Plot Style* – shows the plot style of the particular layer,
- *Plot* – shows if particular layer is plottable or not plottable,
- *New VP Freeze* – *Thaw/Freeze* feature applied for the new Viewports, not for the whole drawing,
- *Description* – layer's description.

1.4.1 Quick Select

Quick Select is a very useful tool, also in 3D modeling application. It enables quick selection of particular group of objects for further modifications without the necessity of selecting the necessary elements one by one. The most common way of Quick Select method access is by context menu of the Drawing Area (right button of the mouse) or QSELECT command. After Quick Select method is chosen the characteristic dialog (Fig. 1.15) appears.

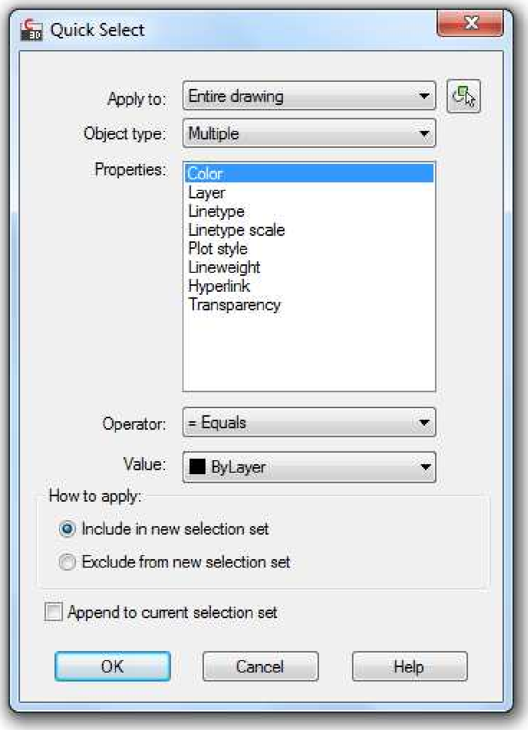

Fig. 1.15. Quick Select dialog window

Working with Quick Select method relies on selection particular objects with characteristic parameters values like Color, Layer, Linetype etc.

1.4.2 Layers Isolate

Layers isolation helps to quickly modify objects with common *Layer* parameter. After particular Layer is isolated it can be hidden or blocked which helps in free selection or modification of other, non blocked elements.

Access to *Layers Isolate* tool is available by the *Isolate* icon on *Layers* Panel or by LAYISO command. After *Layers Isolate* is called, the following subcommand appears:

Select objects on the layer(s) to be isolated or [Settings]:

Selection of any object results in isolation of the Layer with the selected object. Sub-option *Settings* enables modification of *Layers Isolate* command behavior:

Enter setting for layers not isolated [Off/Lock and fade] <Lock and fade>:

Off sub-option hides the isolated layer, *Lock and fade* results in locking the whole layer and decreasing of its visibility.

To restore all layers from being isolated, LAYUNISO command or *Unisolate* icon should be used.

1.5 Coordinates systems in AutoCAD

The ability to work with coordinates is essential for efficient AutoCAD program handling. In the three-dimensional space it is possible to apply the following coordinates systems (*Abott, 2007; Jaskulski, 2009; Finkelstein, 2000; Finkelstein, 2009; Finkelstein, 2011*):

- Cartesian Coordinates: *x,y* (2D mode) or *x,y,z* (3D mode),
- Polar Coordinates: $r<\varphi$ (2D),
- Cylindrical Coordinates: $r1<\varphi,r2$ (3D),
- Spherical Coordinates: $r<\varphi1,\varphi2$ (3D).

Coordinates can be input as:

- direct coordinates (according to start point defined as *0,0,0*),
- indirect coordinates (according to the previous drawn point).

The most popular and effective way for regular drawing is the indirect system of coordinates. It eliminates the necessity of recalculation of the particular objects dimensions according to 0,0,0 point.

1.5.1 Cartesian Coordinate System

In the two-dimensional drawings, the Cartesian Coordinates are the couple of numbers, separated with comma (,), (.) is a separator of decimal numbers for floating point values. Cartesian Coordinates marked as: *x,y* are the direct Cartesian Coordinates and as *@dx,dy* – indirect coordinates which mean the increase of the value in comparison to the previous points.

In three-dimensional space there is one more dimension available (height – *z*), perpendicular to the *x,y* plane. That's why the Cartesian Coordinates in direct form are the following*: x,y,z* and in indirect form: *@dx,dy,dz*. It must be underlined here, that the values of particular dimensions are not the real lengths of modeled objects but their projections according to the suitable planes. Fig. 1.16 presents three axes of the 3D Cartesian system.

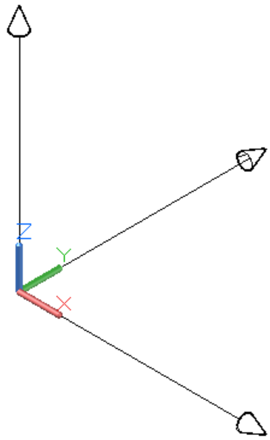

Fig. 1.16. Three axes defining the Cartesian 3D system

Direct coordinates are rarely used both in 2D and 3D modeling (*Finkelstein, 2000*). Indirect system seem to be more practical and efficient.

The example of positioning of any point in three-dimensional space is presented at Fig. 1.17.

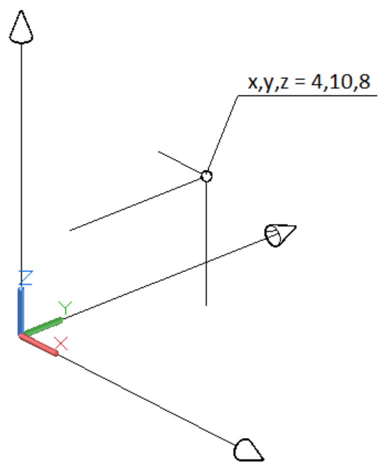

Fig. 1.17. Positioning of the particular point in 3D space using Cartesian Coordinate System

1.5.2 Polar Coordinates

Polar Coordinates (direct and indirect) are mostly applied for the two-dimensional drawings. It must be mentioned here that they are the base for other 3D coordinate systems (cylindrical and spherical), presented in the next subchapters.

Fig. 1.18 presents four examples of particular points set in the direct Polar System. For the Polar system it is required to determine the real length (not projection, comparing to the Cartesian Coordinates) of the object and its rotation angle according to the X-axis. As a default, the positive rotation direction is counterclockwise (it can be modified in AutoCAD environment setup), but it seems senseless from the point of view of typical program operating. With inputting the negative angle value it is possible to draw an object in clockwise direction.

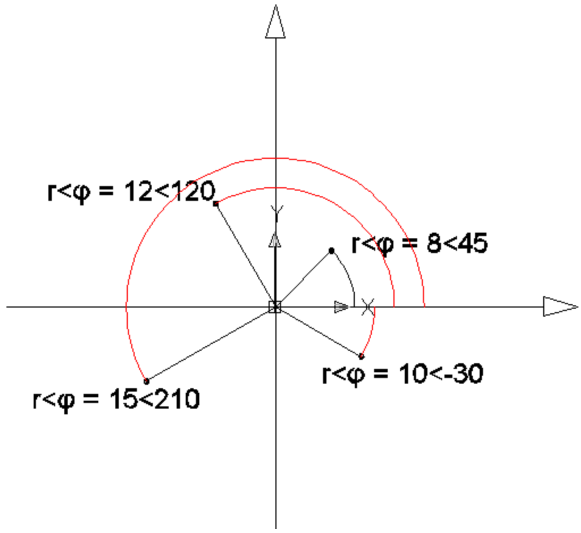

Fig. 1.18. Application of Polar Coordinates in a 2D plane (*Suchorab et al., 2010*)

1.5.3 Cylindrical Coordinates

Cylindrical Coordinates are the developed version of Polar Coordinates and are typical for the 3D modeling. Their formal notation is the following: *@r1<φ,r2*, where (*Finkelstein, 2000; Finkelstein, 2009; Finkelstein, 2011*):

- *r1* – distance between the beginning of the coordinates system (direct coordinates) or previous point (indirect coordinates „@") in XY plane,
- *φ* – angle according to the X-axis in the XY plane,
- *r2* – distance according to the Z-axis of the Cartesian System (perpendicular to the XY plane).

None of the *r1* and *r2* values is the real length of the lines drawn. *r1* and *r2* should be treated as the legs of the right-angled triangle, and the real length is the hypotenuse (Fig. 1.19). It can be easily calculated with Pythagorean theorem or checked in AutoCAD using DIST or LIST commands.

Fig. 1.19 presents the lengths of the legs of the right-angle triangle, which are the following: *r1=8, r2=15*. Angle in the XY plane is 30°, so to draw the line it is required the position of the second point in the following way *(@)8<30,15*. Length of the drawn line is 17 units in real.

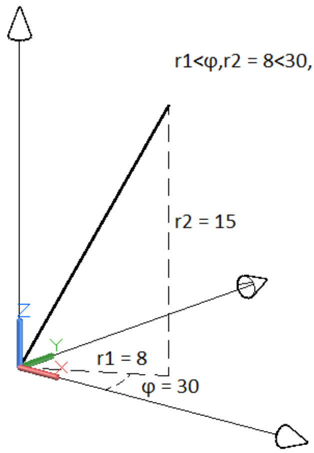

Fig. 1.19. Drawing a line in 3D space using the Cylindrical Coordinates

1.5.4 Spherical coordinates

Spherical coordinates, similarly to the cylindrical ones are the complicated version of polar coordinates, where to determine the position it is required to input the real value of the drawn line, angle in relation to the X-axis in XY plane and finally, the angle in relation to the XY plane in the direction according to the Z-axis (*Finkelstein, 2000; Finkelstein, 2009*). That's why the form of spherical coordinates is the following*: r<φ1, φ2*, where:

- *r* – real distance between the endpoint and start point,
- *φ1* – angle in relation to the X-axis in XY plane,
- *φ2* – angle in relation to the XY plane, according to the Z-axis (Fig. 1.20).

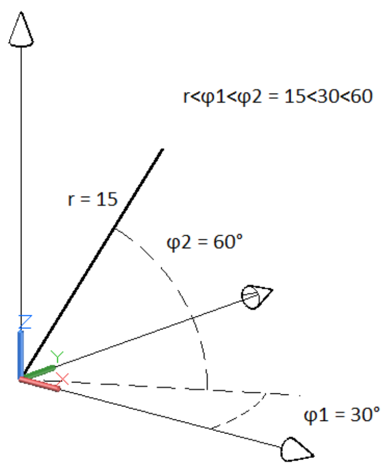

Fig. 1.20. Drawing of a line in 3D space using Spherical Coordinates

1.6 Global and User Coordinate System (UCS)

To make working with AutoCAD 2012 more effective, it is important to apply the possibility of switching between different coordinate systems (*Abott, 2007; Allen and Onstott, 2007; Jaskulski, 2009; Finkelstein, 2000*). It is especially important for 3D modeling, but also quite helpful during working with typical, 2D drawings. In default, each user of AutoCAD works in the Global Coordinate System (GCS). But often there are circumstances, when it is necessary to use extra coordinate system, depending on user – for example during working with development plans, when the main road crosses other, the minor one under the angle of 30°, for example (Fig. 1.21).

For efficient work with the minor road and its surroundings it is sensible to rotate the coordinate system for the angle of 30°, which would enable quick operating of the buildings, networks, water and sewage pipes, parallel or perpendicular to the minor road (Fig. 1.22).

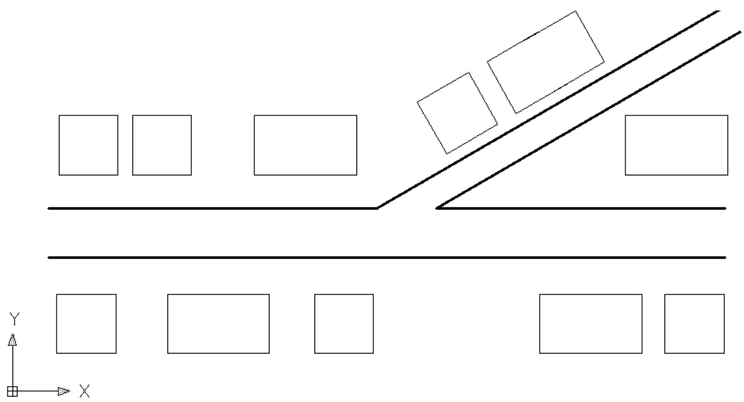

Fig. 1.21. Main road and the minor one at the angle of 30° (*Suchorab et al., 2010*)

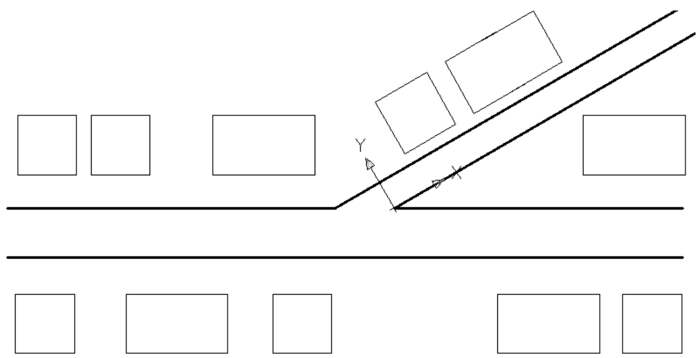

Fig. 1.22. Setting the User Coordinate System (UCS), enabling easy objects operation in relation to the minor road (*Suchorab et al., 2010*)

In the above presented situation, the beginning of the new User Coordinate System is set at the beginning of the minor road, and X- and Y- axes are parallel and perpendicular according to it.

To switch between the alternative User Coordinate Systems, UCS command should be used or suitable icon chosen from the *View* Ribbon and *Coordinates* Panel, which would provide the suitable control over the different coordinate systems. For the effective application of the UCS facility, it is suggested to practice the potential possibilities of this tool. In case of the roads presented in Fig. 1.22 and Fig. 1.23, the easiest seems to choose "*Z*" option, which rotates the coordinate system around the axis perpendicular to the XY plane for the suitable angle – 30° in this particular case. Another solution is to use the *OBject* sub-option and click the default line at an angle of 30°. The program will generate a new coordinate system, setting the X-axis parallel to the handled object and the beginning of the new coordinate system will be placed at the starting point of the selected object.

An essential facility during working with many coordinate systems it is the possibility to save the previously user-defined coordinate systems (UCS), which offers the possibility to return to the previous coordinate system settings. It is especially helpful during modeling in 3D environment. To save the previously defined coordinate system, *NAmed* sub-option of UCS command should be applied or suitable icon clicked at the *Coordinates* panel (visible on Fig. 1.23). After the *NAmed* sub-option is applied, another, *Save* sub-option should be available, which would enable to save the new, user-defined coordinate system.

Quick return to the Global Coordinate System (GCS) is possible by using the *Global* option or by clicking the suitable icon with Earth's globe symbol (Fig. 1.23).

A very efficient tool which enables user friendly management and switching between the previously defined coordinate systems is *Named UCS Combo Control*, which can be found in *Coordinates* panel (Fig. 1.23).

Similar results may be obtained by UCS *NAmed* command sub-option, which enables to *Restore* any saved and named coordinate systems. The only condition to use this tool is to enter the user-defined name of this system. In such a case, when previously given name of user-defined system is forgotten, it is possible to use help system (choosing "*?*" and then "*" symbols) which would call the Command Line Window (Fig. 1.11) with listing of all the previously saved coordinate systems.

The alternative tool for management of coordinate systems is the User Coordinate System Manager (Fig. 1.24), available under UCSMAN command or suitable icon at *Coordinates* panel.

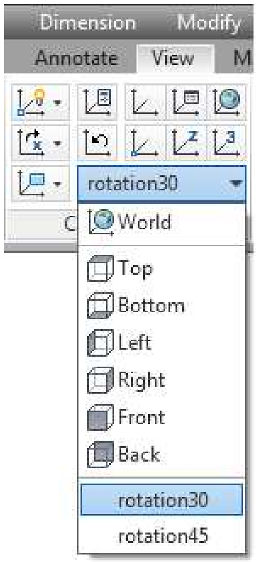

Fig. 1.23. Named UCS Combo Control enabling quick changes of particular predefined and user-defined coordinate systems

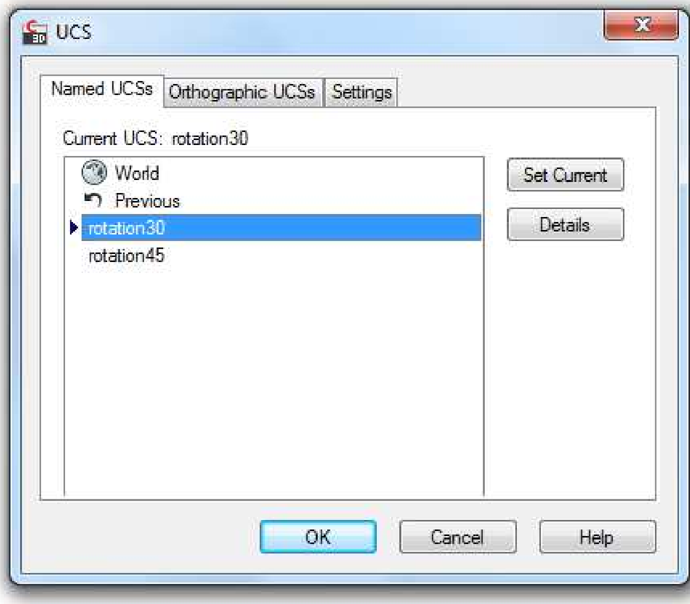

Fig. 1.24. User Coordinate System Manager

1.7 *UCS Icons*

An essential improvement enabling to draw in the three-dimensional space is the UCS icon, which represents the directions of the particular coordinate axes. It precisely shows which system of coordinates is active (*Jaskulski, 2009*). The appearance of the UCS icon is controlled by UCSICON command, which enables to:

- turn on the icon visibility (*ON*),
- turn off the icon visibility (*OFF*),
- set the UCS icon in the starting point of the coordinate system (*ORigin*),
- set the UCS icon in the left-down corner of the screen, not the starting point of the coordinate system (*Noorigin*),

Also, there is a possibility to modify the properties of the UCS Icon (*Properties*). Access to the above mentioned functions is also enabled by *UCS Icon, Properties…* Icon at Coordinates panel, which activates UCS Icon window (Fig. 1.25) to manage the UCS Icon properties like style, size or even color.

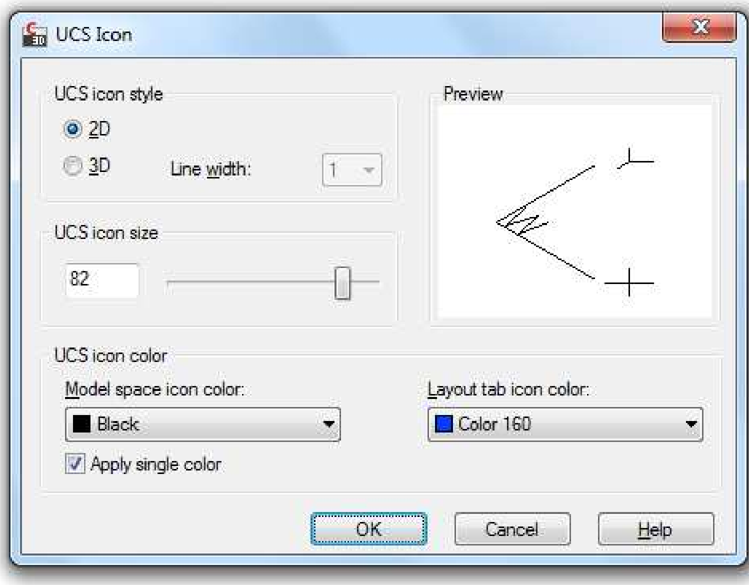

Fig. 1.25. UCS Icon window

Fig. 1.26 shows the particular types of icons demonstrating the coordinate systems in two-dimensional projection. The first icon on the left shows the X and Y directions in Global Coordinate System (World). Second icon represents User Coordinate System ("W" symbol is not visible) and the third example icon show the directions of the User Coordinate System axes, which are rotated in space.

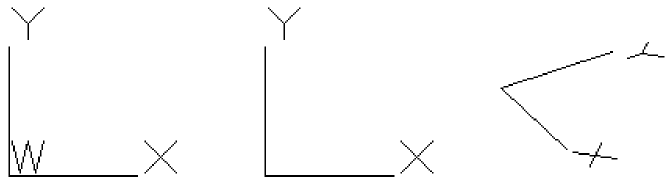

Fig. 1.26. Types of two-dimensional UCS icons in AutoCAD2012

UCS Icons presented at Fig. 1.27 show three-dimensions and could be applied in 3D modeling. The left icon is less important. It shows 3D coordinate system during working in 2D Wireframe visual style. The icon presented on the right is valid for most of the 3D drawings. It directly indicates that three-dimensional visual style of 3D objects mapping is active. Visual styles of three-dimensional objects will be described in detail in the further part of this book.

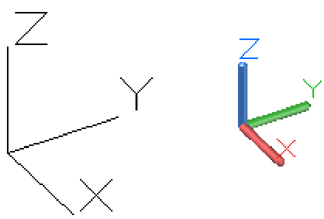

Fig. 1.27. Three-dimensional types of UCS icons in AutoCAD 2012 (left – 2D visual style, right – 3D visual style)

1.8 Working in the three-dimensional space

During drawing in AutoCAD 3D a very important role plays good sense of direction and space orientation. For flat, two-dimensional drawing quite sufficient tools are ZOOM and PAN which enable zooming and moving the drawings.

In case of the 3D objects, ZOOM and PAN are still useful but their application is strongly limited. This is caused by complicated, spatial character of the 3D models. The most useful and efficient tolls aiding 3D modeling, enabling visualization from any angle are:

- Views,
- ViewCube,
- SteeringWheels,
- Orbit,
- Viewports.

1.8.1 Views

Views tool is especially designed for working in the three-dimensional space. Access to that feature in the *3D Modeling* interface is available by the *View* Ribbon (Fig. 1.28).

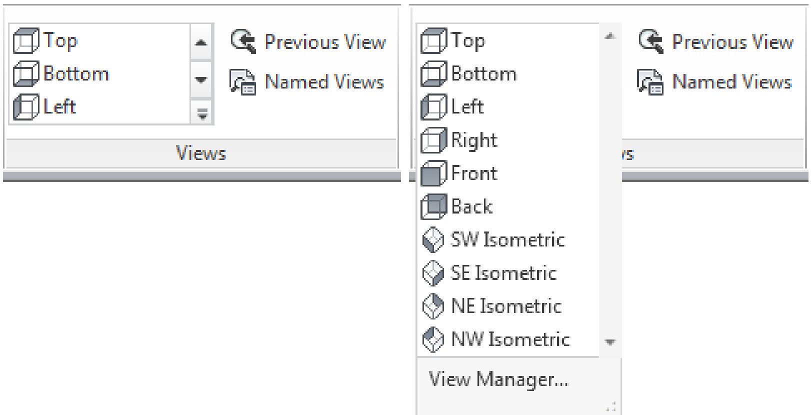

Fig. 1.28. Views Panel of the View Ribbon, enabling observation of modeled objects from different positions in the three-dimensioanl space

Described tool enables objects observation from several pre-defined simple views:

- Top,
- Bottom,
- Left,
- Right,
- Front,
- Back

And four isometric views:

- SW Isometric,
- SE Isometric,
- NE Isometric,
- NW Isometric.

The additional tool for views management is *View Manager* (Fig. 1.29) which can be execute by *Views* Panel, *Named View* Icon or VIEW command.

It must be underlined here, that *View Manager* enables switching between particular pre-defined views (*Preset Views*) but also creation of user defined views (*New*) and management of them.

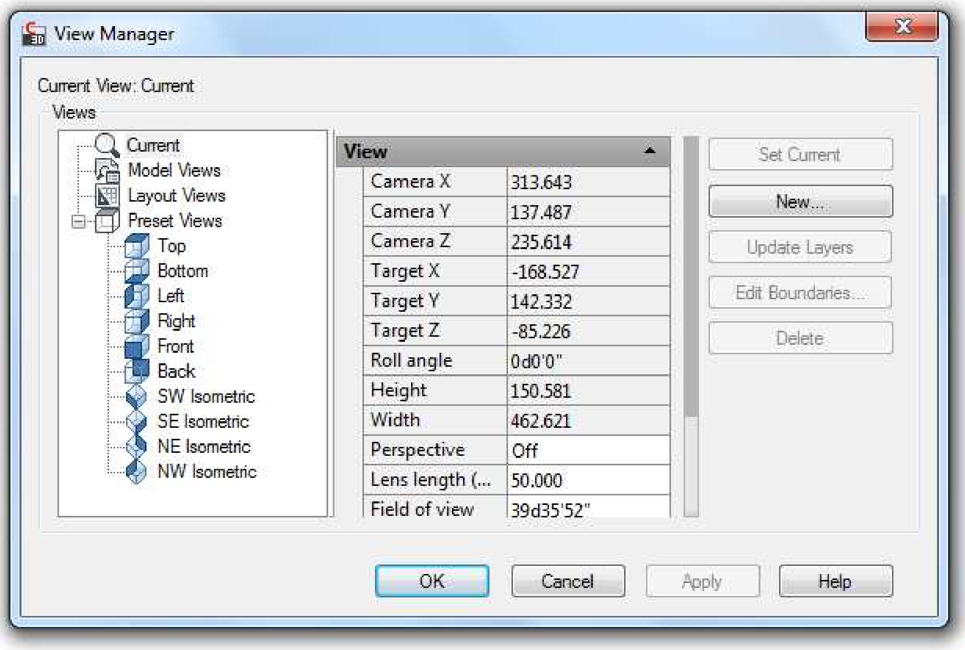

Fig. 1.29. *View Manager* dialog of AutoCAD 2012

1.8.2 ViewCube

ViewCube tool presented at Fig. 1.30 enables presentation of three-dimensional objects only in 3D view.

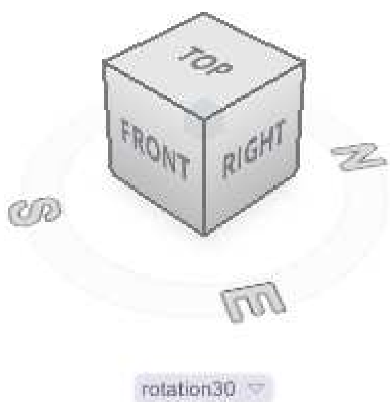

Fig. 1.30. *ViewCube* of AutoCAD 2012

It is a very useful feature of latest AutoCAD editions, offering many possibilities for 3D designing (*Finkelstein, 2009, Finkelstein, 2011*). Working with *ViewCube* relies on clicking or dragging the highlighted fragments of the cube or compass around it. *ViewCube* feature can be controlled by NAVVCUBE command and its sub-options: *ON*, *OFF*, *Settings*.

During operating in 3D, *ViewCube* is normally inactive and partially transparent until the cursor appears above it. Cursor activates the *ViewCube* tool and makes it clearly visible and ready to be used.

ViewCube enables quick and efficient switching between particular standard view directions. There are the following cube fragments to be chosen (*Finkelstein, 2009*):

- one of eight vertices,
- one of twelve edges,
- one of six walls
- *Home* – return to the main view.

Access to many interesting options of *ViewCube* feature is available from the context menu.

1.8.3 Steering Wheels

Steering Wheels is a useful tool both for working in 2D and 3D environment (*Jaskulski, 2009*). Working with the discussed feature relies on selecting of highlighted functions of the *Steering Wheels* tool (Fig. 1.31).

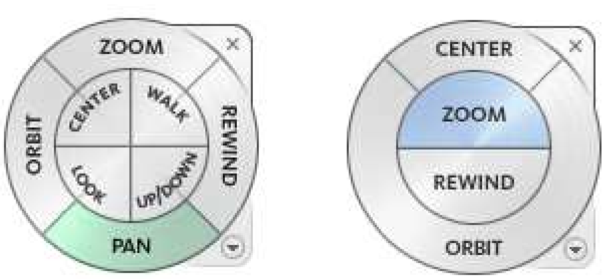

Fig. 1.31. Example views of *Steering Wheels* in AutoCAD 2012
(left in 3D mode, right 2D mode)

Steering Wheels can be quickly activated by *Navigate* panel of *View* ribbon (Fig. 1.32) and *Navigation Bar* (Fig. 1.33), typically placed in the right side of the Drawing area, partially transparent like *ViewCube*.

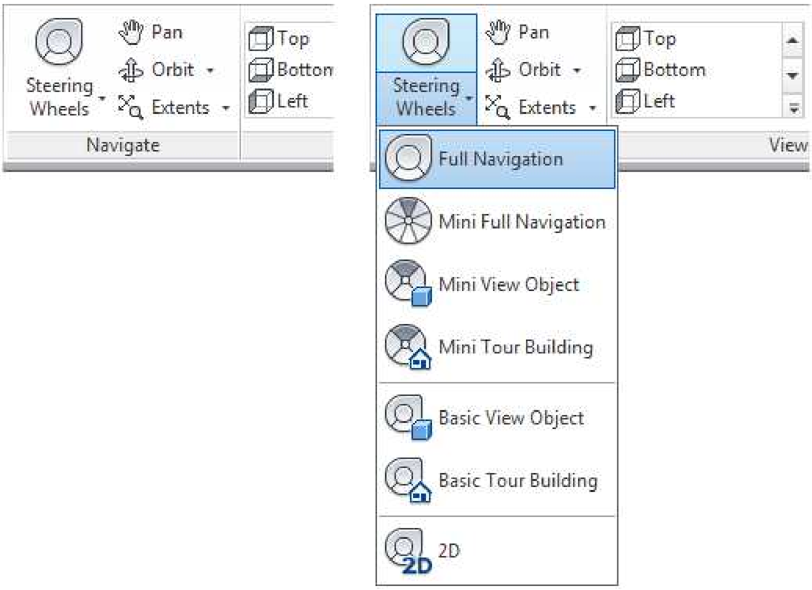

Fig. 1.32. View ribbon with Steering Wheels options

Fig. 1.33. Navigation bar

During operating, *Steering Wheels* follows the cursor. After the expected part of the wheel is highlighted, left mouse button should be pressed, which would enable view navigation using the traditional techniques of AutoCAD like ZOOM, PAN, ORBIT etc.

Besides the typical, full-scale *Steering Wheel* mode, there are small versions of the discussed tool. They are accessible by the context menu or directly from the Ribbon Panel.

During working with *Steering Wheels* AutoCAD works in navigation mode, which means that drawing or editing is not possible. For quick deactivation of the *Steering Wheels* and switching to working mode, the best solution is to press Escape button (or choose *Close Wheel* option from the context menu). To obtain more experience in *Steering Wheels* application it is strongly recommended to practice the functionality of the discussed feature.

1.8.4 Orbit

3D Orbit is probably one of the most efficient features during working in 3D objects (*Finkelstein, 2000; Finkelstein, 2009; Finkelstein, 2011*). In AutoCAD 2012 it can be executed by many methods, for example it can be 3DORBIT (*Orbit*), 3DFORBIT (*Free Orbit*). Other access options are the following:

- icon at *Navigate* Panel of the *View* Ribbon in *3D Modeling* interface,
- using Main Menu of AutoCAD 2012,
- context menu of many navigation tools *Pan*, *Zoom* or *Steering Wheels*,
- combination of *Shift* keyboard button and inner mouse button.

It must be mentioned here that last of the above presented ways of *Orbit* access is the most effective because it enables rapid switch into the 3D orbiting mode without giving any commands or finding the suitable icons.

During *Orbit* use, AutoCAD works in special navigation mode – so called 3D orbiting and thus drawing of the modeled objects is not available then, only their preview, analogically to the *Steering Wheels* feature.

The advantage of *3D Orbit* over other navigation tools is the possibility of object presentation under any angle and distance depending on user current needs. Also, simplicity of operation, makes it the most efficient navigation tool for 3D modeling environment. Fig. 1.34 shows an example of *Free Orbit* application.

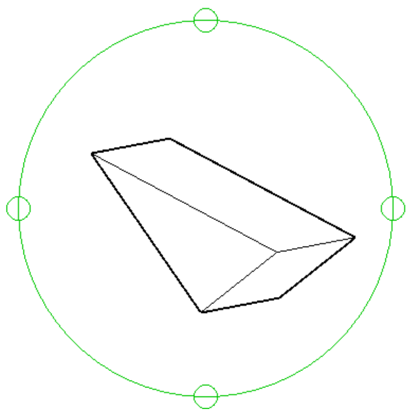

Fig. 1.34. *Free Orbit* (3DFORBIT) arcball for navigation in three-dimensional space of AutoCAD 2012

For the needs of this elaboration, working in orbiting mode will be presented using the *Free Orbit* tool. When *Free Orbit* becomes active, an arcball with four small circles appears (Fig. 1.34). The small circles are placed in characteristic points of the arcball – quadrants. During orbiting mode, there are available different types of cursors (Fig. 1.35) which determine the way of modeled objects rotation (*Finkelstein, 2011*):

- Circular Arrow Cursor (1 on Fig. 1.35) – appears outside the arcball. Modeled 3D object is rotated (rolled) around the imaginary axis perpendicular to the screen.
- Sphere and Lines Cursor (2 on Fig. 1.35) – appears inside the arcball. Modeled object is rotated around the center of the arcball in the dragging direction. Application of this cursor enables model rotation for the angle of 360°.
- Horizontal Ellipse Cursor (3 Fig. 1.35) – appears at horizontal quadrants of the arcball. Enables 3D object rotation around arcball's vertical axis.
- Vertical Ellipse Cursor (4 on Fig. 1.35) – appears at vertical quadrants of the arcball. Enables 3D object rotation around arcball's horizontal axis.

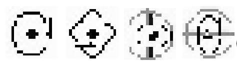

Fig. 1.35. Cursors available in *Free Orbit* mode (*Finkelstein, 2011*)

To exit navigation (orbiting) mode *Escape* button should be pressed or *Exit* option selected in context menu of the discussed tool.

1.8.5 Viewports

Working with complicated three-dimensional models is especially facilitated by the possibility of simultaneous view of modeled objects from many directions, using separate projection planes. It is especially inevitable for the beginners in 3D modeling using AutoCAD and mainly caused by the fact that flat screen does not suitably projects the three-dimensional construction of discussed objects. The most frequent situation is when from the main projection plane the modeled object looks correctly and after is rotation or other change of perspective it looks spoiled. This is mostly caused by the fact that 3D objects look different in layered and project perspective. The possibility of using of the multiplied projection with the application of *Vieports* enables to eliminate any chances of mistake. The only limitation of the discussed solution is the screen area consumption which becomes less important in recently produced display units exceeding 20 inches in diagonal. Such large panels enable to sacrifice enough area both for working vieport and for several ones used as preview.

Command which is mainly used to call *Vieports* is VPORTS. After its application *Viewports* dialog appears (Fig. 1.36). Other way to switch between particular projections configuration is to press the suitable icon on *Vieports* Panel of *View* Ribbon or choose it from AutoCAD Main Menu, *Vieport* option. Anyhow it should be underlined that the application of *Viewports* manager seems to be the most effective and user friendly.

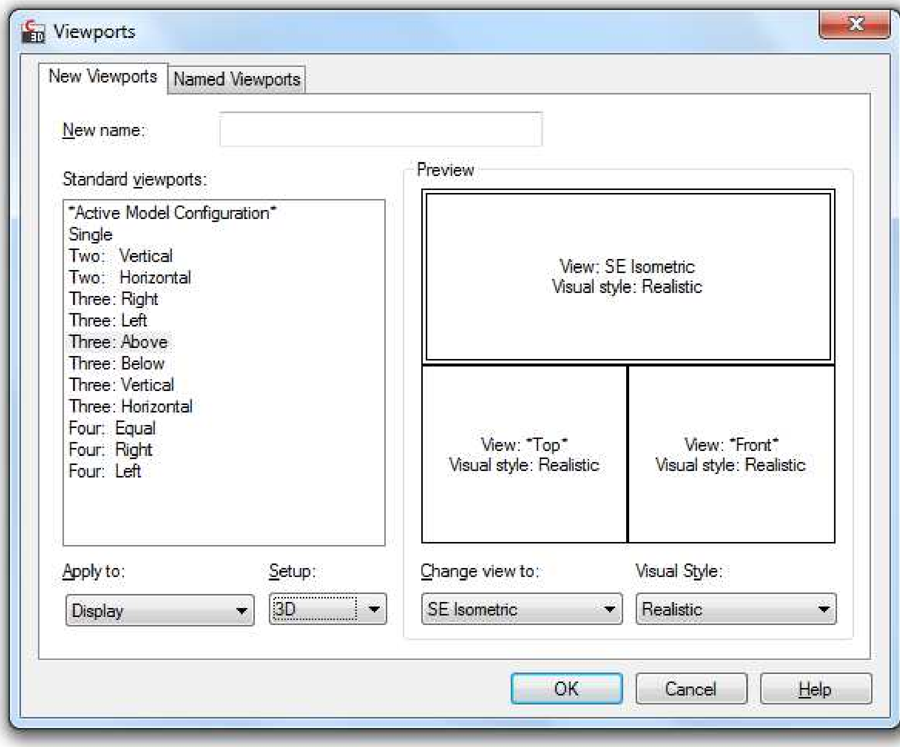

Fig. 1.36. *Viewports* manager window

1.9 Clipping Planes

Other, useful function of AutoCAD 2012 is *Clipping Planes* feature, which may be used to clip particular parts of the modeled objects and eliminate some elements from the projection and thus show the internal details of the modeled construction. For example external envelopes or ceilings constructions disable the visibility of indoor equipment. Practical application of the discussed tool will be more extensively presented in further part of the elaboration.

There are two types of clipping planes:

- Front Clipping Plane, hiding all elements placed in front of it,
- Back Clipping Plane, hiding all elements placed behind it.

Clipping Planes can be called using 3DCLIP command. After the 3DCLIP command is entered, *Adjust Clipping Planes* dialog window appears (Fig. 1.37). *Clipping Planes* are parallel to the display plane and in the above mentioned dialog there is presented the projection from the above, perpendicular to the display plane with two visible lines. Black line represents the front clipping plane in the real model and the pink line represents the back clipping plane in the real model.

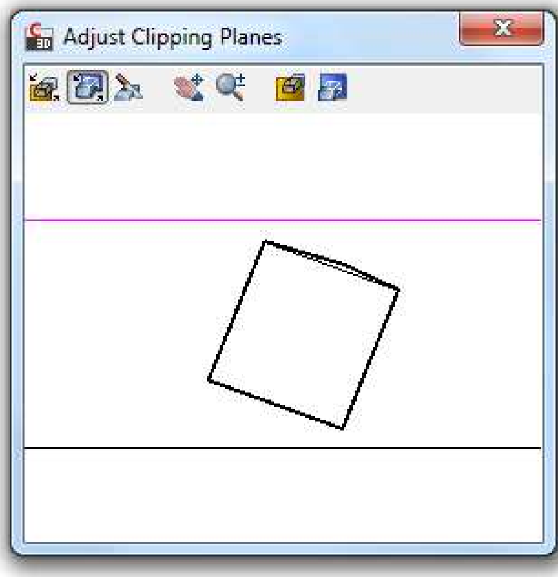

Fig. 1.37. *Adjust Clipping Planes* dialog window

First two icons in *Adjust Clipping Planes* dialog are used for selection of the front or back *Clipping Plane*. The third icon – *Create Slice* is used for simultaneous movement of the front and the back clipping plane.

To turn on/off the *Front Clipping Plane* it is necessary to set the black line (representing front *Clipping Plane*) and then press the sixth icon of the dialog window menu presented on Fig. 1.37. This icon turns the front clipping line on/off. Back clipping line is turned on/off by the seventh icon of the discussed dialog menu. Both (sixth and seventh) icon pressed eliminates the model elements from the front and the back of the objects. Fourth and fifth icon of the described dialog window are applied for navigation (PAN and ZOOM).

Also it is important to underline that application of *Clipping Planes* does not cut or modify the real objects. It only influences the projection of the described objects, not the objects themselves.

1.10 Parallel and Perspective Projection

Standard operating of AutoCAD 3D drawings uses parallel projection of the modeled objects. That means, that all edges parallel in real are projected in parallel mode. This can be visualized by the left solid on Fig. 1.38. In perspective projection it seems that all edges of the visualized object are converging in the distance, running towards the common point (right solid).

In everyday's working it seems more sensible to work in parallel projection mode – it is more convenient and provides better control over the modeled three-dimensional objects. Perspective projection makes the obtained results more reliable, models visualized in perspective are suggesting depth which is not possible in flat, parallel projection mode.

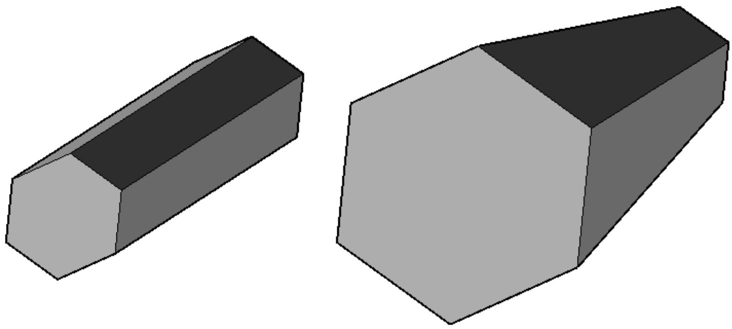

Fig. 1.38. Parallel projection (left object) and perspective projection (right object)

To switch between two discussed modes of projection it is necessary to enter the navigation mode (PAN, ZOOM, ORBIT) to use *Orbit* feature. In navigation mode it is possible to activate context menu and choose one of required modes of projection: *Parallel*, *Perspective*. Other possibility to change the projection mode is to use context menu of ViewCube, where is offered the possibility to change projection mode into *Parallel*, *Perspective* and *Perspective with Ortho Faces* style.

Also it ought to be mentioned here, that older editions of AutoCAD did not enable drawing and editing in perspective projection mode, it was only used for visualization and presentation needs. The latest editions offers operating in both modes, anyhow, as it was mentioned in the previous paragraph, the authors of this book suggest using parallel mode for everyday's use.

1.11 Visual Styles

During working with 3D models it is important to use a suitable *Visual Styles* of three-dimensional objects representation. It means that modeled objects can be presented in several ways. Among visualization modes, those predefined styles are the most important:

- *2dwireframe*,
- *3dhidden*,
- *3dwireframe*,
- *Conceptual*,
- *Realistic*,

- *Shaded*,
- *Shaded with edges*,
- *Shades of Gray*,
- *Sketchy*,
- *Wireframe*,
- *X-Ray*.

Switching between particular modes is available using SHADEMODE command with above modes represented as sub-options or by using the right Panels at *Home* or *View* Ribbons (Fig. 1.39).

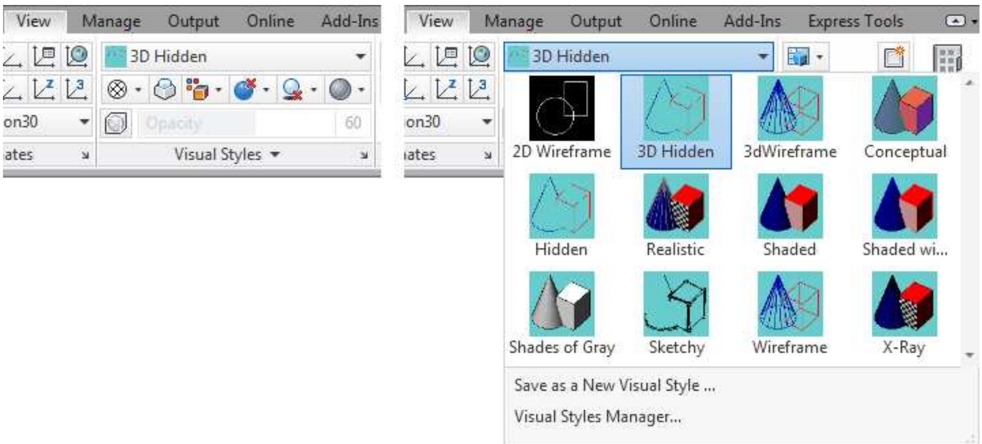

Fig. 1.39. Panel *Visual Styles* in *View* Ribbon

AutoCAD 2012 enables management of visualization styles and the possibility of widespread modification of the predefined, above enumerated styles. The most useful feature for that aim is *Visual Styles Manager* presented on Fig. 1.40. *Visual Styles Manager* can be called using VISUALSTYLES command or *Visual Styles* Panel (Fig. 1.39).

Visual Styles Manager enables management and modification of the visualization parameters in predefined styles, but also it enables to create new visual styles, which will not be described in this book and should be tested by the interested reader on his own.

Two first visualization modes are wireframe models, which means that 3D objects are presented as wireframes. It must be clearly underlined that wireframe visual style does not mean that presented object is a wireframe. It is only the mode of 3D projection and can be available for any three-dimensional object of AutoCAD. Wireframe visual style is a handicapped mode because it does not represent the real features of modeled objects.

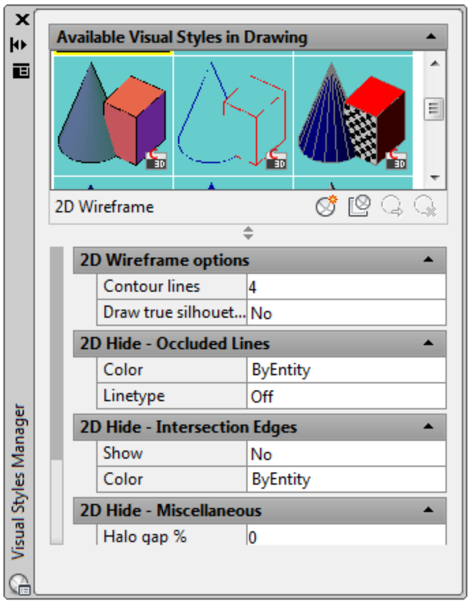

Fig. 1.40. Visual Styles Manager

To control the quality of 3D models representation in wireframe mode it is used ISOLINES system variable (*Finkelstein, 2000; Finkelstein, 2009; Finkelstein, 2011*), which value is set to 4 in default. Increasing the value of ISOLINES variable improves the quality of visualization but may decrease the velocity of computer performance. ISOLINES variable is only used in wireframe modes and cannot be used in different modes of 3D models visualization. Interesting projection of ISOLINES application is presented on Fig. 2.13 during presentation Solid Sphere in the next chapter of this book.

3Dhidden and *Hidden* styles are still wireframe models, but much more interesting from the previous two. Comparing to wireframes, they hide the invisible lines and edges making the presented objects more realistic.

Next modes of visualization are more advanced and enable better 3D models representing. *Conceptual*, *Shaded*, *Shaded with edges* and *Shades of Gray* modes introduce some reality to the presented objects. This reality is obtained by different shades of grey or other colors at each surface of particular element, that's why presented objects look better than wireframes. This type of visualization offers the efficient preview of modeled objects and enables quick and easy operating with relatively small computer resources consumption.

Realistic visual style is the most advanced model of projection used in AutoCAD. It offers the most realistic representation of the modeled 3D objects, paradoxically it is not convenient for regular operating – it may slow the computer performance and not always provides clear visualization of the objects. The most important advantage of *Realistic* visual style is the ability to assign the textures of materials to particular modeled objects from material database, which would make the drawings close to reality and good preview for rendering.

Rendering is the most advanced way of 3D objects visualization. It relies on generation of flat, raster pictures with the quality comparable to photography. Rendered pictures are generated using 3D objects modeled in AutoCAD. Rendering relies on using the textures, lights, shades etc. and will be more precisely presented in further part of this book.

1.12 Rendering

Among *Visual Styles* the most significant place take *Rendering*. It should be underlined, that it is not a typical *Visual Style*. This is the most advanced visualization technique applied for 3D models. Using this technique it is possible to obtain raster figures with photographic quality on the basis of the modeled 3D objects.

This sub-chapter presents the theoretical bases of rendering technique and the practical implementation will be presented in the last part of the book. The most important rendering elements are (*McFarland, 2009; Omura, 2009; Finkelstein, 2011*):

- *materials,*
- *light,*
- *background,*
- *fog,*
- *shadows.*

To obtain the most realistic effects it is required to customize all above mentioned parameters. Command that calls rendering procedure is obvious: RENDER, anyhow before the rendering is proceeded all necessary parameters should be suitably configured. Access to rendering module is available by *Render* Ribbon of *3D Modeling* interface.

Materials

AutoCAD 2012 is supported with Materials Library with wide range of applicable materials. They differ in character – many of them are textures, representing the surface of such materials as wood or concrete. There can be also masonry fragments with particular bricks distribution but also glaze or terracotta tiles. Other parameters are valid for such materials like metals or glass.

The most important parameters characterizing the materials are: *Color, Image, Image Fade, Glossiness, Highlights, Reflectivity, Transparency, Translucency, Refraction, Cutouts, Self Illumination, Bump*. Access to all materials features is available by *Materials* Panel of *Render* Ribbon or even using MATERIALS command. The most important windows for materials configuration are *Materials Editor* and *Materials Browser* which will be presented in the further, practical part of this book.

Light

Second most important parameter set in rendering procedure is light. It significantly determines the renders quality and visual attractiveness. AutoCAD 2012 offers the following types of light:

- *Sun*, simulating the sun, enabling various models lightning depending on geographical location and daytime. Settings of sun light are collected in *Sun & Location* Panel of *Render* Ribbon.
- *Point light*, according to its name is generated by point source like candle or bulb. It is placed in the particular position, determined by spatial Cartesian coordinates and spreads radial in all directions being suitably attenuated depending on *Attenuation* settings (*None*, *Inverse Linear*, *Inverse Square*). Generation and configuration of *Point light* can be easily made using *Lights* Panel of *Render* Ribbon.
- *Spot light*, comparing to the *Point light*, the *Spot light* is determined by both source position, but also the lightning direction. *Spot light* is a mapping of a reflector or a torch. Most of parameters describing *Spot light* are similar to *the Point light* parameters. Extra parameters determining *Spot light* behavior are *Hotspot angle* and *Falloff angle*, which determine the angle of cone of light.
- *Distant light* is a light type comparable to the *Sun* light, anyhow independent on it. The most important features of *Distant light* are *Intensity factor*, *Filter color* and *Status*.
- *Weblight* is a new type of light, which represents a three-dimensional light distribution and can be used for anisotropic light representation (*http://exchange.autodesk.com*) and thus can give more precise representation of light than above presented *Point light* or *Spot light*.

Background

In default the background of rendered scenes is a uniform (*Solid*) light which is not always satisfactory for advanced rendering options. AutoCAD 2012 offers the particular types of the background which can be applied in rendered scenes:

- *Solid* – uniform background,
- *Gradient* – with two or three colors,
- *Image* – bitmap which serves as a background of the rendered 3D models.

Access to background configuration is available using *View Manager* presented at Fig. 1.29, *New* Button.

Fog

Application of fog in the rendered scenes increases their reality. This is caused by the fact that real air transparency is never absolute. It must be underlined that using of fog in rendering settings increases the rendering procedure and should be turned on in the recent renderings. Access to fog settings is available using RENDERENVIRONMENT command or *Environment* option at unfolded *Render* Panel at *Render* Ribbon. Using or the discussed feature results in *Render Environment* dialog window appearing with basic fog settings available.

Shadows

Shadows increase the reality of the rendered scenes. Similarly to the fog, their application strongly influences rendering process duration. AutoCAD 2012 enables to use two types of shadows:

- *Ground Shadows* with simpler algorithm of shadows mapping,
- *Full Shadows* with the advanced algorithm of shadows mapping.

It should be mentioned, that selection of particular shadows type should depend on several factors, mostly computer set parameters. Access to shadows features is available using *Lights* Panel, *Render* Ribbon or using VSSHADOWS command.

Rendering procedure is executed using RENDER command or using *Render* Icon at *Render* Panel. Anyhow it should be remembered that before it is started, all necessary, above presented parameters should be adjusted. Also, it should be mentioned here, that more settings related to rendering procedure is collected in a special window: *Advanced Render Settings* which can be called out by clicking a small arrow at *Render* Panel. Among them, the following settings could be important in further part of this book:

- *Procedure* (*View*, *Crop*, *Selected*), which determines which part of the model will be rendered,
- *Destination* (*Window*, *Viewport*), determining where the rendered scene will be presented (*Window* option results in targeting the rendering scene to the external window where the results can be previewed or saved in raster file type),
- *Output size*, determining the resolution of rendered result,
- and many other features which will not be widely discussed in this book.

As it was mentioned at the beginning of this sub-chapter, rendering is a very sophisticated visualization tool, which is not possible to be presented in several pages. Application of it requires some practice which will be presented in the final part of this elaboration.

2 3D Modeling

The previous chapter is devoted to the basics of AutoCAD 2012 using, with special attention put onto working in three-dimensional space. There are presented the most important tools and their utility in modeling of three-dimensional objects.

Second chapter of this book is devoted to the basic rules of 3D objects modeling. There are presented the types of three-dimensional objects and the methods of their modeling and editing.

2.1 Wireframe model

Wireframe models are the simplest representation of the three-dimensional objects. Wireframes consist of two-dimensional lines, curves, polylines, closed polylines (rectangles, squares, polygons) oriented in the 3D space. That’s why skilled users in 2D drawings operating should have no problems with adaptation to the wireframe 3D modeling. Wireframe models still can be modified as in a 2D plane, using the extra dimension according to “z” axis. For example it is possible to move any object upwards or downwards using the traditional 2D command MOVE, with the following displacement: *0,0,Z*, where *Z* means distance of the displacement in a vertical direction. An example wireframe object is presented on Fig. 2.1which was created using lines and closed polylines (rectangles) in the three-dimensional space.

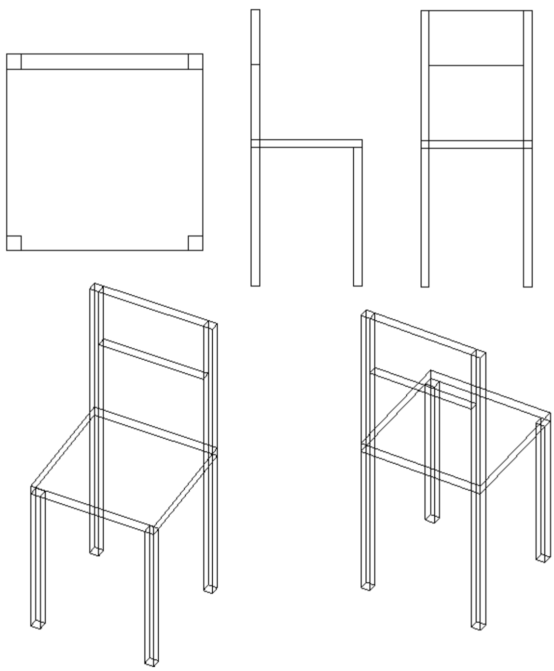

Fig. 2.1. Particular projections of wireframe object – a chair (*Suchorab et al., 2010*)

It is very important to be careful during working with COPY function. For example, copying a wireframe object upwards it is not visible in plane projection, because new objects may hide the original – that's why application of observation aids like *Orbit*, *Steering Wheels*, *ViewCube* or *Viewports* is suggested, especially for the beginner users.

Other important thing, improving working with 3D wireframe (and other types) models is the use of the following drawing aids – *Object Snap – Endpoint*, *Midpoint*, *Center* etc. which are typically used in flat drawings and will not be further discussed.

As it was mentioned above, wireframes are not real 3D models. That's why they do not behave like real three-dimensional objects. For example, elements which are closer to the observer do not hide elements behind them, they are empty inside and thus cannot be applied for modeling of realistic drawings.

2.2 2½D Objects

The simplest method to obtain more realistic results than wireframes it is to add thickness parameter to the flat objects. Such elements are still not the typical 3D objects. That's why they are called two and half dimensional (*Finkelstein, 2000*) or pseudo-spatial objects (*Jaskulski, 2009*). They possess the third dimension but created walls are always straight and perpendicular to the initial two-dimensional object.

To convert a simple flat element into 2½D object it is necessary to assign a suitable value to *Thickness* feature in *Properties* window of the object. In default *Thickness* property value equals zero and is typical for the flat elements. Value different from zero means pseudo-spatial objects. In case of the negative *Thickness* property value, generated objects are converted into pseudo-spatial elements in opposite direction than in default (Fig. 2.2).

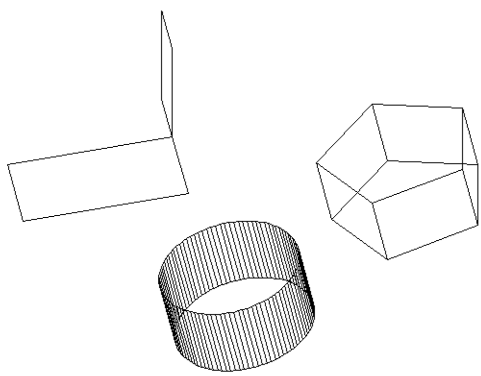

Fig. 2.2. 2½D objects created using *Thickness* feature with flat elements (*Suchorab et al., 2010*)

An interesting information for working in the three-dimensional space is the ability to set the actual level (elevation) of the drawn object. The default level is zero (according to “z” axis, perpendicular to “x,y“ plane).

To change the initial values ELEV command should be used which results as the following dialog:

Specify a new default elevation <0.0000>:

Specify a new default thickness <0.0000>:

It is visible in the commands presented above, the new elevation and the new thickness will be assigned to all generated objects which means that if we enter a new value different from zero, all generated object will be pseudo-spatial. To control this parameters (elevation and thickness) two separate AutoCAD system variables are also applied – ELEVATION and THICKNESS.

Comparing 2½D elements to the wireframes it is important to understand that they have surfaces (not only wires) that’s why more distant elements could be hidden by the closer objects. To check this feature of pseudo-spatial objects, HIDE command can be used which result is presented at Fig. 2.3. It is the same set of 2½D objects as at Fig. 2.2 after HIDE command is used.

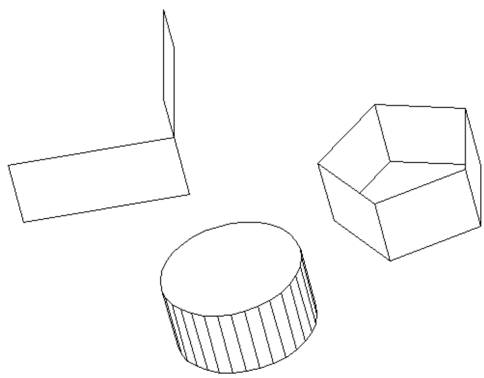

Fig. 2.3. 2½D objects after using HIDE command (*Suchorab et al., 2010*)

Also, it must be mentioned here, that practical application of 2½D objects in professional 3D modeling is strongly limited.

2.3 3D Surfaces

More complicated from wireframes and pseudo-spatial objects type of three-dimensioanal objects are 3D Surfaces, also known as meshes or faces. Meshes structure enables hiding parts of distant elements, shading and thus better visualization. In practice they can be also applied for topologic plans elaboration (*Wedding and McEachron, 2009*).

Anyhow it must be underlined that meshes are still handicapped 3D objects especially because of lack of such properties as mass, centre of gravity etc. That's why practical application of meshes is rather limited comparing to other, more realistic objects like solids, more precisely discussed in the next subchapter of this book.

Access to 3D Surfaces is available using *Mesh* Ribbon in *3D Modeling* interface. Also it is possible to use Main Menu and *Draw* option, *Modeling* and *Surfaces* or *Meshes* sub-option. Of course, another possibility is typing suitable commands in Command Line.

Basic meshes types are contained in the *Primitives* panel of *Mesh* Ribbon (Fig. 2.4) and there are *Mesh Box*, *Mesh Cone*, *Mesh Pyramid*, *Mesh Sphere*, *Mesh Wedge and Mesh Torus*. Also there are contained four more tools useful during working with meshes, which enable formation of more complicated objects:

- REVSURF – *Revolved Surface*,
- RULESURF – *Ruled Surface*,
- TABSURF – *Tabulated Surface*,
- EDGESURF – *Edge Surface*.

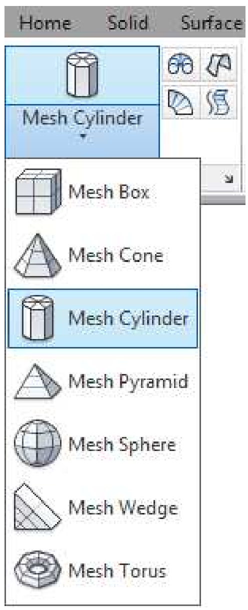

Fig. 2.4. *Primitives* Panel of *Mesh Modeling* Ribbon

Operating on meshes is comparable to solids, that's why it is assumed that each reader of this sub-chapter will be able to create basic 3D Surfaces analogically to solids presented in the next sub-chapter.

Summarizing the most important information about 3D Surfaces it must be underlined, that they are easy editable, which significantly increases their practice applicability in modeling. They can be edited using mouse by selecting, dragging and dropping or with special dialogs like presented in Fig. 2.5, where tessellation, smoothness level etc. can be adjusted. This dialog window can be executed using *Mesh* Ribbon and *Primitives* Panel.

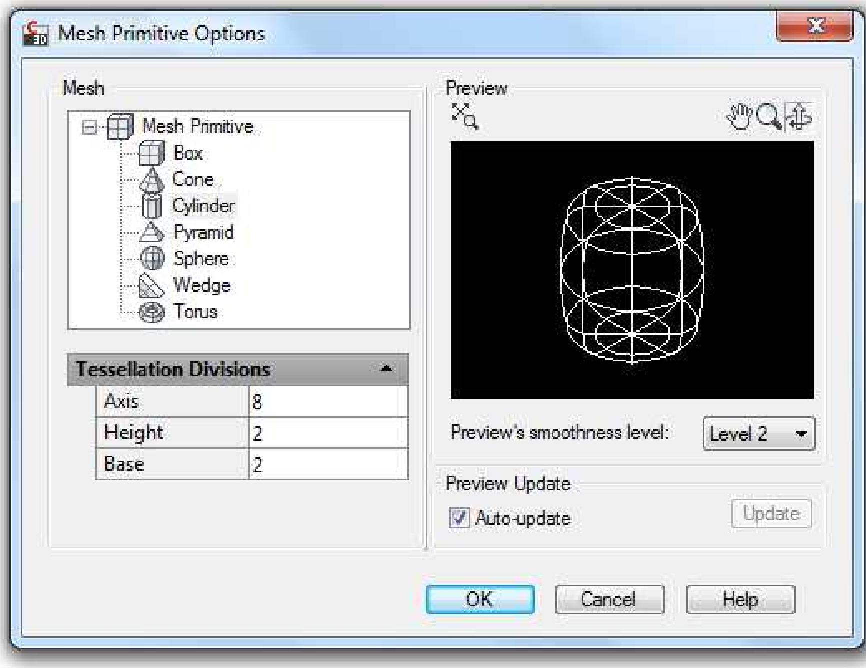

Fig. 2.5. *Mesh Primitive Options* dialog useful in management, edition and generation of mesh primitives

Finally it is worth mentioning here, that 3D Surfaces are easily convertible into solids which makes them fully useful 3D objects with great modeling potential.

2.4 Solids

As it was previously underlined, the solids are the most important 3D objects for modeling. They are the most attractive real objects representatives. Comparing to 3D Surfaces, which are empty inside, solids are characterized by full three dimensions. The most important solids features are (*Jaskulski, 2009*):

- three-dimensional geometry,
- physical properties, typical in real objects, e.g. mass, centre of gravity, moment of inertia, which can be checked by MASSPROP command,
- ability of modification (slicing, lengthening etc.).

All advantages presented above result in their attractiveness in 3D modeling, that's why the most attention is put on them in the following elaboration. Also it must be mentioned here, that third, practical chapter of this book will be mainly focused on 3D modeling using the solids.

Access to tools connected with solids modeling is available using *Home* or *Solid* Ribbon in *3D Modeling* interface (Fig. 2.6, Fig. 2.7).

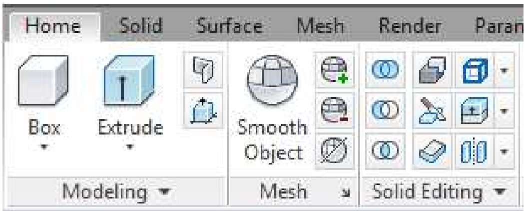

Fig. 2.6. *Home* Ribbon of *3D Modeling* interface

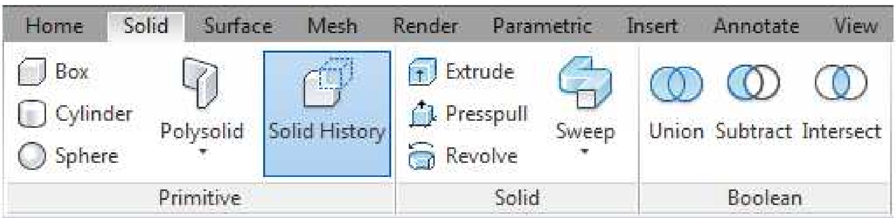

Fig. 2.7. *Solid* Ribbon of *3D Modeling* interface

After the *Box* icon is clicked it expands and other icons appear, which can be used to generate primitive solids. Among them there are: *Box*, *Cylinder*, *Cone*, *Sphere*, *Pyramid*, *Wedge* and *Torus*. Also, besides *Box* icon there is a set of icons for modeling of more complicated solids: *Extrude*, *Loft*, *Revolve*, *Sweep*, and further *Polysolid*, *Presspull*.

Other important Panel o *Home* Ribbon, connected to 3D modeling is *Solid Editing* Panel with solid edition tools.

Other way of working with solids is to use AutoCAD Main Menu – *Draw* – *Modeling* or direct typing of commands which will be presented in the further part of this book, together with details of the particular solids.

2.4.1 Solid Primitives

Solid primitives are the easiest type of solids that's why they are mostly applied for generating most of 3D models. Of course they can be also used for modeling of complicated 3D objects using edition commands and functions which will be presented in further part of the book.

Box

Box (Fig. 2.8) is the main primitive solid. Drawing of box relies on generation of 3D model by giving its all dimensions: base (two dimensions) and the height. After the BOX command is called, the following sequence appears:

Specify corner of box or [Center]:

Specify corner or [Cube / Length]:

Specify height or [2Point]:

The result of the following commands is a three-dimensional solid. It is possible to give direct and indirect coordinates or simply using the mouse, showing the suitable points. Using the *Cube* sub-option enables quick cube-box formation with only one dimension entered.

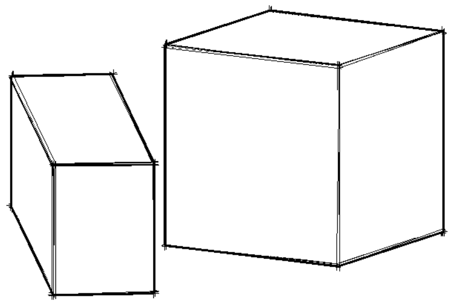

Fig. 2.8. Box-shaped solids generated using BOX command in *Sketchy Visual Style*

Sphere

Sphere (Fig. 2.9) is another solid primitive. Comparing to the mesh-sphere, it must be underlined that it is full inside. Solid sphere is generated with a simple command – SPHERE with the following sequence of sub-commands:

Specify center point or [3P/2P/Ttr]: (position of sphere center in 3D space),

Specify radius or [Diameter]: (sphere radius dimension or „d” to establish the sphere diameter).

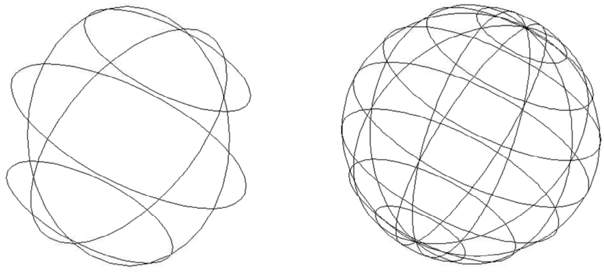

Fig. 2.9. Solid Spheres presented in *2dwireframe* mode with two ISOLINES variables values (4 – left sphere, 10 – right sphere)

Cylinder

Cylinder (Fig. 2.10) is a solid primitive with two parallel, round-shaped (or elliptical) bases. After the CYLINDER command is called, the following command sequence occurs:

Specify center point for base or [3P/2P/Ttr/Elliptical]:

Specify base radius or [Diameter]:

Specify height or [2Point/Axis endpoint]:

To generate the cylinder with elliptic base "e" should be chosen during the above sequence.

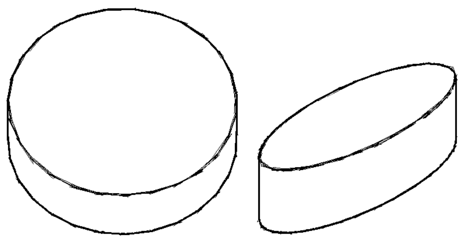

Fig. 2.10. Examples of cylinders generated using CYLINDER command

Cone

Cones (Fig. 2.11) are generated comparably to cylinders. To create a solid cone it is necessary to specify the position, the dimensions of the base (elliptical variants are also here available) and the height. This is obtained using sequence:

Specify center point of base or [3P/2P/Ttr/Elliptical]:

Specify base radius or [Diameter]:

Specify height or [2Point/Axis endpoint/Top radius]:

It is also possible to generate frustum of a cone (Fig. 2.11 – right). To obtain such a solid, it is necessary to specify the radius of its top base using the following sub-option from the above sequence – *Top radius*, and then set the height.

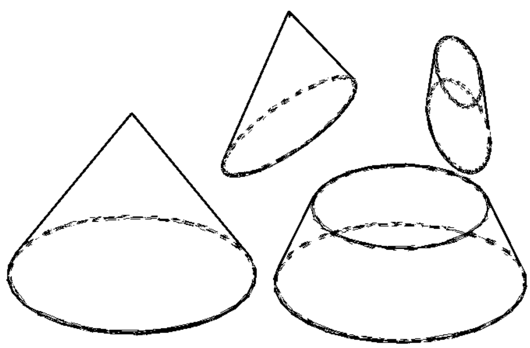

Fig. 2.11. Cones obtained using CONE command presented in modified *Sketchy Visual Style*

Wedge

Wedge is a cuboid, cut along one of its diagonals. Formation of a resembels cube formation and the whole dialog of sub-options is analogical. The examples of wedges are presented on the Fig. 2.12.

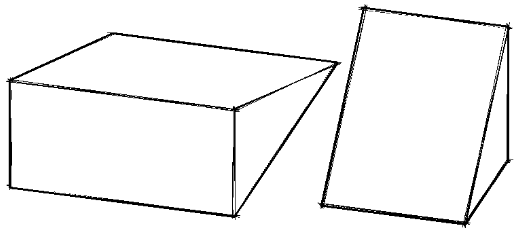

Fig. 2.12. Example wedges formed using WEDGE command

Torus

According to its name – *Torus* is a toroidal solid (Fig. 2.13). Formation of torus requires to set the centre of the whole solid and two diameters or radii – first is the dimension of the whole torus, and the second one is a tube dimension. Torus can be formed using TORUS command, the procedure is the following:

Specify center point or [3P/2P/Ttr]:
Specify radius or [Diameter]:
Specify tube radius or [2Point/Diameter]:

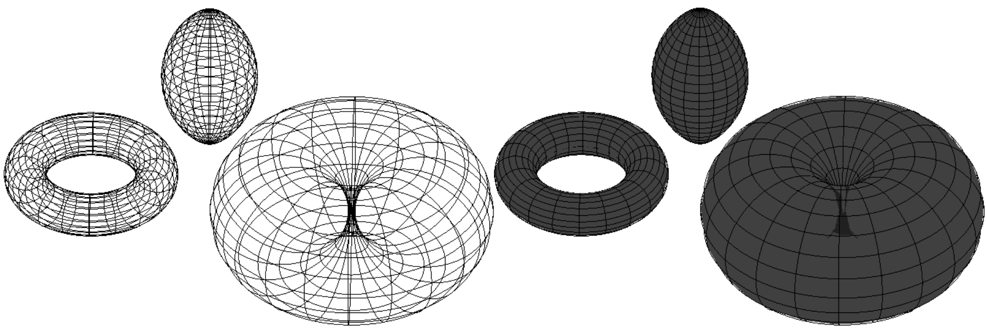

Fig. 2.13. Solids generated using TORUS command, above – wireframe model, below – *X-Ray* Visual Style

It must be underlined that TORUS command enables to generate many interesting solids which could be used in many ways in 3D modeling (*Finkelstein, 2011*). For example – negative value of whole torus radius and the unsigned value of its tube radius greater from the whole torus creates a lemon or rugby ball. On the other hand setting the tube diameter grater from the whole solid diameter results in apple-shaped solid (Fig. 2.13).

Pyramid

Pyramid is a solid presented on Fig. 2.14. By default it is defined by the base dimension and the height. AutoCAD enables formation of pyramids with different number of sides (*Sides* sub-option) and frustum of the pyramid (*Top radius*).

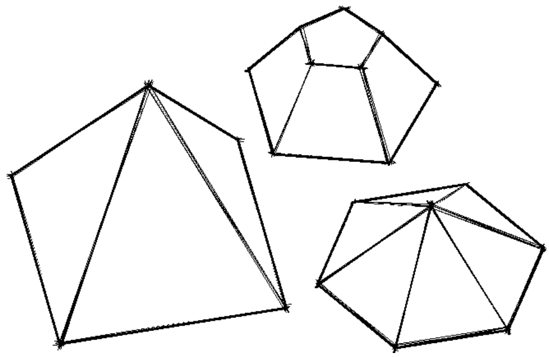

Fig. 2.14. Pyramids in *Sketchy Visual Style*

As the other AutoCAD features, pyramid modeling can be executed using PYRAMID (or PYR) command. Also it can be called using suitable icons from *Home* or *Solid* Ribbons. The default sequence of subcommands in pyramid formation is the following:

Specify center point of base or [Edge/Sides]:
Specify base radius or [Inscribed]:
Specify height or [2Point/Axis endpoint/Top radius]:

Sequence which changes number of sides and generates the frustum of the pyramid:

Specify center point of base or [Edge/Sides]: s
Enter number of sides <4>:
Specify center point of base or [Edge/Sides]:
Specify base radius or [Inscribed]:
Specify height or [2Point/Axis endpoint/Top radius]: t
Specify top radius:
Specify height or [2Point/Axis endpoint]:

2.4.2 Advanced solids

All above presented solids are the real 3D objects. Anyhow they are simple in construction and their application in real 3D models can be limited in advanced visualizations. AutoCAD enables formation of more complicated 3D objects using special commands for generation of 3D object. Also it is possible to obtain the satisfying results by modification of the solid primitives presented in sub-chapter 2.4.1.

Extrude / Sweep

EXTRUDE command enables extrusion of 3D solids (or 3D Surfaces) from the flat, two-dimensional objects. Among them are:

- closed, two-dimensional polylines,
- rectangles,
- polygons,
- circles,
- ellipses,
- closed splines.

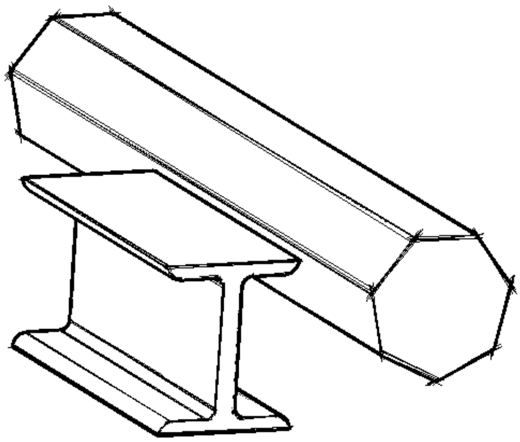

Fig. 2.15. Examples of solids obtained using EXTRUDE function

It must be mentioned here, that after the closed 2D profile is extruded into the 3D solid, it is normally removed as a source of the solid. Such an attempt seems to be sensible, because it enables to avoid the excessive objects and mess in the operated space. Anyhow it is possible to save the existing profiles (for further use or in case of any mistakes). To store the base extrusion profiles there can be applied the DELOBJ system variable, which can accept two values – 0 and 1 (*Finkelstein, 2011*). The default value of DELOBJ variable is set into 1, which means that the initial profiles are removed. Its change into 0 results in storing the initial, flat profiles. It can be suggested here, that it is a good habit to store the mentioned profiles in an extra layer, reserved for such objects, which can be hidden during drawing.

Formation of 3D solids by flat profiles extrusion seems to be simple and easy. It relies on profile selection and specification of the extrusion details. Extrusion command can be called using the suitable icon or typing the EXTRUDE command. The whole formation proceeds according to the example dialog of sub-commands:

Select objects to extrude or [MOde]:

Specify height of extrusion or [Direction/Path/Taper angle/Expression]:

It's worth underlining here, that sub-command *MOde* was introduced to AutoCAD in the most recent editions of software. It offers the choice of the expected, extruded 3D model between the Solids and the 3D Surfaces, and will not be further described in this chapter.

In standard the walls of the created solid are parallel to each other (perpendicular to the initial profile (Fig. 2.16). Anyhow it is possible to change the angle of extrusion which is presented at Fig. 2.17.

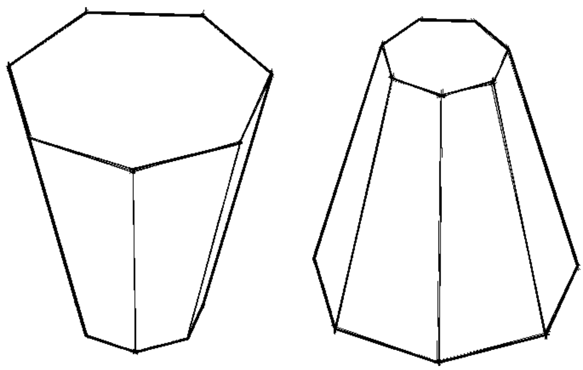

Fig. 2.16. Profiles extruded with narrowing and widening walls

In order to narrow the walls during extrusion, a suitable sub-option should be chosen in the above presented dialog – *Taper angle*. Positive angle value means narrowing and the negative one – widening. It must be remembered that in case of narrowing, the angle should not be too big, because it may result in extrusion failures.

Other, useful feature of extrusion is to use *Path* for extrusion. The *Path* should be previously defined by the user. It is a very interesting function of AutoCAD which enables formation of very sophisticated 3D objects (Fig b). The suitable path can be determined using the following objects: lines, arcs, ellipses, polylines and splains.

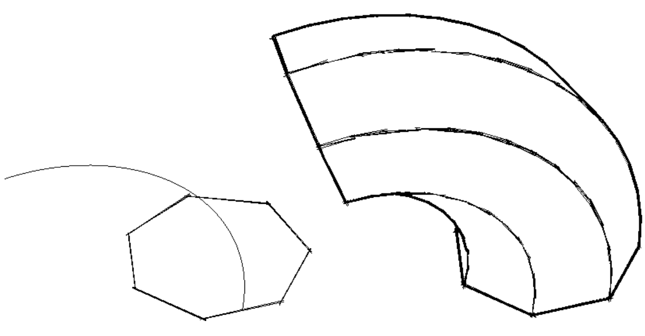

Fig. 2.17. Extrusion of a closed profile using *Path*

Application of a *Path* sub-option is only possible when the extruded profile and the mentioned path are not in the common plane. To prepare the suitable extrusion path, a good improvement seems to be the change of Global Coordinate System (GCS) into the User Coordinate System (UCS).

Also, it must be mentioned here that sometimes extrusion using *Path* sub-option may fail. This may be the result of improper path configuration. The following rules should be kept during path preparations (*Finkelstein, 2000*):

- paths should not be too close to the extrude profile,
- paths should not be too complicated,
- in case of the great objects, should not be too twisted.

The above limitations are directly connected to the computer performance and sometimes may behave differently on particular computers.

It must be mentioned here that feature comparable to extrusion with *Path* is SWEEP command, which also enables formation of 3D solids and surfaces by sweeping 2D or 3D profiles along a path. That's why this function will be no longer presented in this book. Interested readers should check the possibilities of SWEEP function and test in at their own computers.

Revolve

REVOLVE command enables formation of 3D solids or surfaces by revolution of the closed profiles (Fig. 2.18, Fig. 2.19, Fig. 2.20) according to the revolution axis. Similarly to extrusion, revolved can be: closed, two-dimensional polylines, circles, ellipses, closed splines, etc.

Also, comparably to extrusion, removing of the source profiles is controlled by the DELOBJ system variable. Formation of the revolved solid runs in the following sub-commands sequence:

Select objects to revolve or [MOde]:

Selected source profile should be confirmed with Enter button or right button of the mouse. Next step is specification of the revolution axis. There are several options for that specification – axes *x*, *y* or *z*. Anyhow the most useful it seems to be using the previously prepared axes as a line:

Specify axis start point or define axis by [Object/X/Y/Z] <Object>:

Where *Object* can be a line of revolution. Otherwise it is possible to select both starting point of revolution axis and then axis endpoint.

Specify angle of revolution or [Start angle/Reverse/Expression] <360>:

In the last step of revolution procedure it is required to establish the revolution angle, which in standard is 360° and means that obtained 3D objects are completely closed (Fig. 2.18, Fig. 2.19). Anyhow AutoCAD gives the possibility to generate not complete 3D objects with, cross-sections visible, when revolution angle less the 360° is assigned (Fig. 2.20).

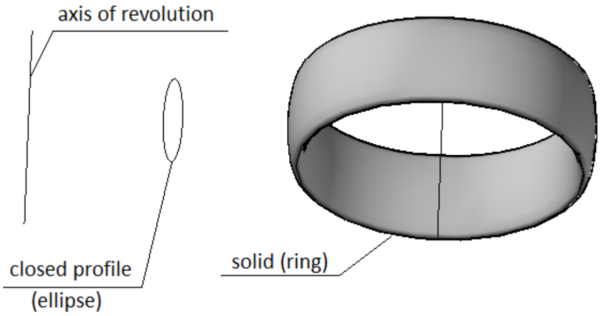

Fig. 2.18. Ring formation using revolution of a closed profile according to a previously prepared axis (revolution angle 360°)

About revolution angle.

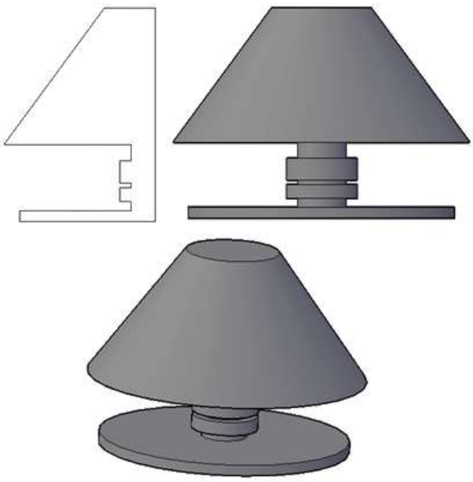

Fig. 2.19. A lamp formed by revolution with the angle of 360° (*Suchorab et al., 2010*)

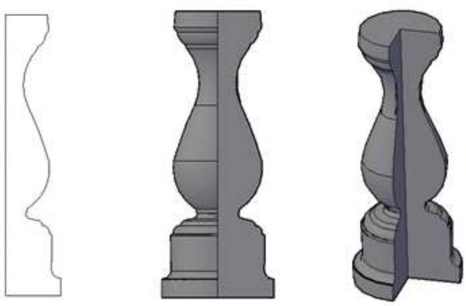

Fig. 2.20. Balustrade banister generated by revolution with the angle of 270° (*Suchorab et al., 2010*)

Loft

LOFT command enables 3D Solids or Surfaces formation by interpolation of particular profiles (Fig. 2.21). Objects obtained with LOFT command may be very complicated, depending on the initial profiles and their distribution. The simplest LOFT command application relies on showing the particular profiles in lofting order and then confirmation.

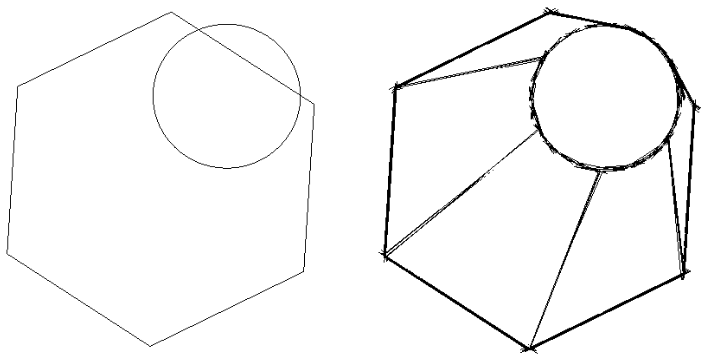

Fig. 2.21. 3D solids formation using LOFT command

LOFT command enables to join different profiles with the walls which finally form the 3D solid. The sequence of sub-commands is the following:

Select cross sections in lofting order [Point/Join multiple edges/MOde]: Enter and option [Guides/Path/Cross sections only/Settings]

Required profiles should be selected and then the next sub-commands confirmed. It must be underlined that lofting operation requires some attention from the user, because it is important to keep the initial profiles in the different planes.

An interesting modification of simple LOFT command is lofting with guides which runs in the following sequence:

Select cross sections in lofting order or [POint/Join multiple edges/MOde]: Enter an option [Guides/Path/Cross sections only/Settings] <Cross sections only>: g Select guide profiles or [Join multiple edges]:

The example of obtained result of lofting operation using guides is presented at Fig. 2.22.

To obtain such a result, two flat polygons were prepared (drawn with thicker line on left above figure). They differed in dimensions and position. Particular points of the polygons were connected with lines which were used as guides during lofting operation. After the sub-option *Guides* was used the interesting 3D solid was formed.

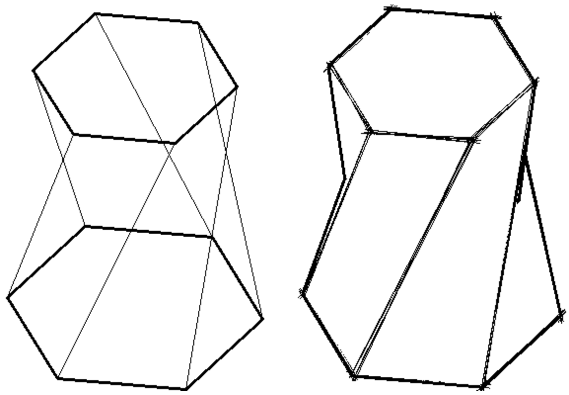

Fig. 2.22. Solid formation with LOFT command using guides (Left – wireframe of cross sections and guides, right lofted solid)

Lofting is a quite complicated feature of AutoCAD 2012 and will not be in detail presented in this book. Otherwise it is strongly recommended to test the full potential of this tool which may be useful in 3D modeling. It is worth mentioning here that some control over lofting procedure is possible to obtain using *Loft Setting* dialog (Fig. 2.23) which can be executed using *Settings* sub-option during *Loft* procedure execution.

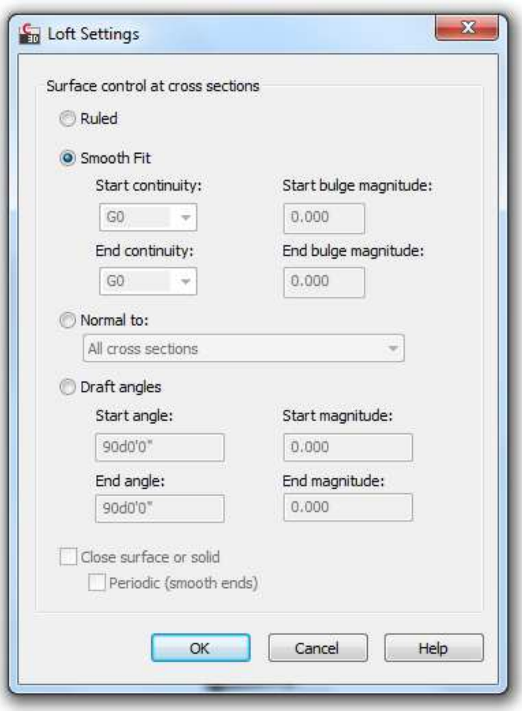

Fig. 2.23. Loft Settings dialog

Polysolid

POLYSOLID command is mostly used by architects drawing walls in 3D. Using of *Polysolid* is similar to *Polyline* with width. To obtain the *Polysolid* it is necessary to assign width, height and then select the particular points like in typical *Polyline*, but the result is a swept solid, using the width previously specified (*Finkelstein*, *2011*).

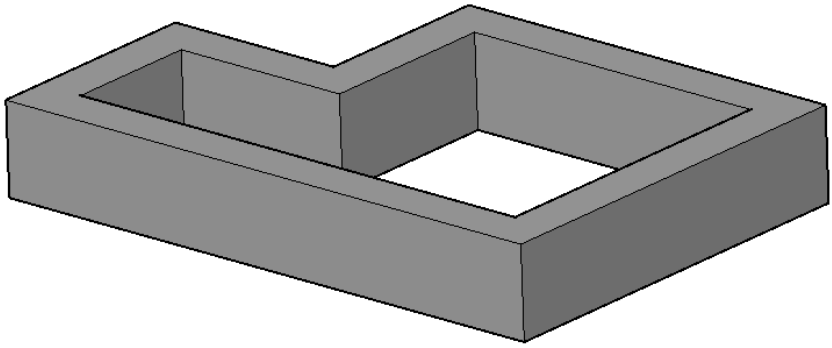

Fig. 2.24. Example of *Polysolid* use at the example of 3D walls formation

Presspull

Similarly to *Polysolid*, *Presspull* seems to be very attractive AutoCAD 2012 feature for 3D walls formation. According to its name it enables pressing or pulling the bounded area by clicking inside area, and then moving the cursor or entering the value to obtain the extrusion effect presented on Fig. 2.25.

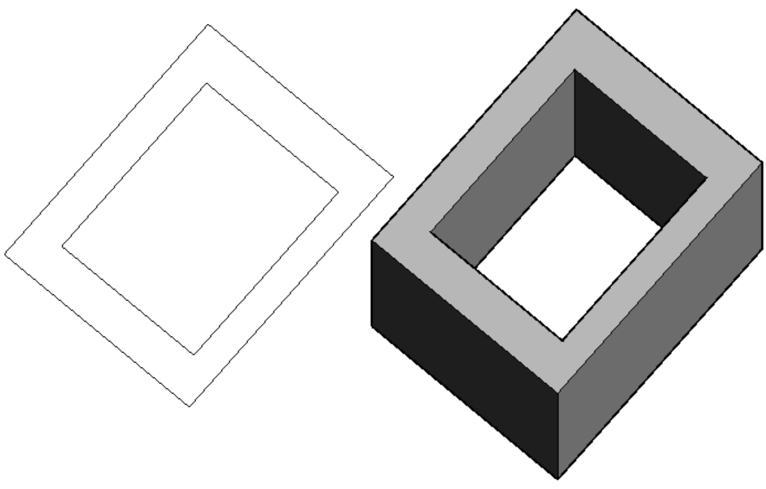

Fig. 2.25. Example of *Presspull* function application

2.4.3 Solids editing

Applying the solid primitives and even advanced solids presented in the previous sub-chapters, it is possible to form the interesting shapes of objects and put them into more complicated forms. Anyhow it still not possible to obtain the required reality. Modification and transformation of the above presented solids may make it possible get more satisfying results.

The simplest techniques of solids modification are Boolean transformations, being the equivalent of logical functions in mathematics.

Union

UNION is the simplest edition command. The result of its application on the several *3D Solids* is a single *3D Solid*. It must be underlined here, that this is only valid in situations, when united solids are interfering. In case of summing with UNION feature, two separate solids (not interfering) are only grouped into a common part, but still do not form a single object.

UNION application is simple and after typing the command or choosing it from the suitable icon the following sub-command appears:

Select objects:

After the suitable solids are selected and the operation is confirmed, the solids are united and form single objects with more complicated geometry (Fig. 2.26).

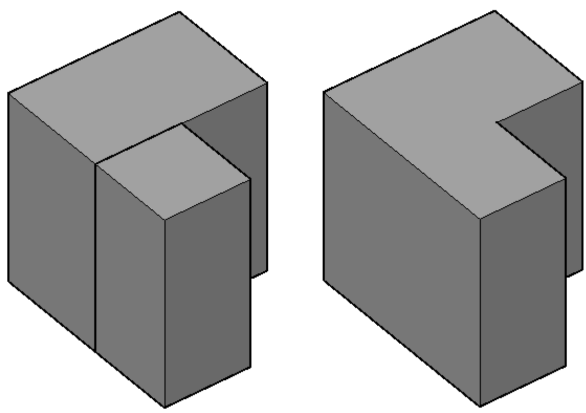

Fig. 2.26. Solid obtained with UNION function

Also, when operating with solids, it must be known that the original solids are removed after UNION functions is used. If the user wants to store them for further application, they should be previously copied and stored in a separate layer, which could be hidden and not disturbing in modeling.

Subtract

SUBTRACT feature enables modeling of complicated and attractive 3D solids by subtracting one solid from the another one. It is especially useful for holes modeling (Fig. 2.27).

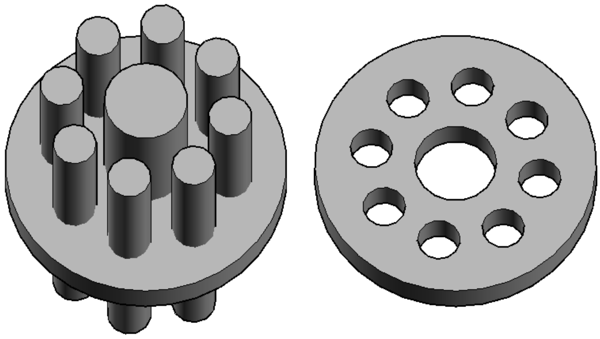

Fig. 2.27. Wholes obtained using SUBTRACT command

The sequence of sub-commands for SUBTRACT functin is the following:

Select solids, surfaces, and regions to subtract from … : (solids which are subtracted from should be selected now)

Select solids, surfaces, and regions to subtract … : (now the solids, which will be removed should be selected).

Intersect

INTERSECT enables formation of complicated 3D solids, being the common part of other solids. Command handling is comparable to UNION command. After typing the command the following sub-command appears:

Select objects:

After the solids selection and suitable confirmation only common parts of the initial solids remain which can be illustrated with the following pictures – Fig. 2.28, Fig. 2.29.

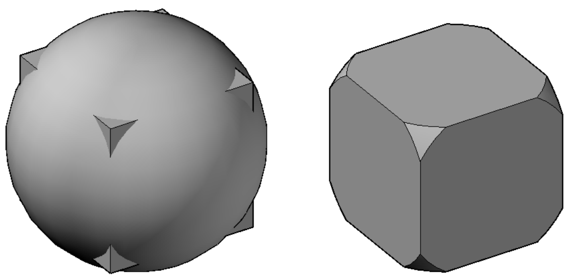

Fig. 2.28. A die model obtained using INTERSECT command on two concentric solids – regular hexahedron and the sphere

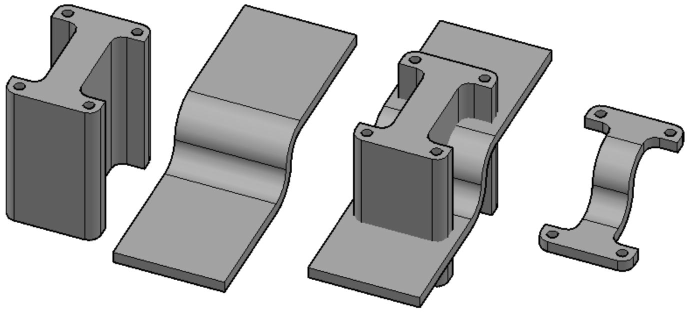

Fig. 2.29. A model of sheet metal obtained using INTERSECT command

Slice

SLICE command is a useful tool for working with 3D models. It may be both applied for 3D solids modeling but also for the presentation aims. With SLICE command it is possible to cut any selected 3D solid and obtain the new objects as result of this operation (Fig. 2.30). It may be applied in many situations:

- separation of particular parts of objects,
- formation of cross-sections,
- modeling of solids with holes and other inequalities in face.

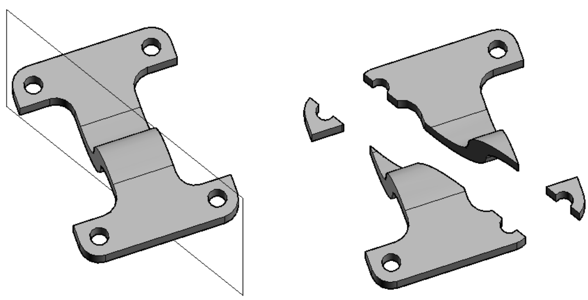

Fig. 2.30. Sliced 3D solid from Fig. 2.29 using SLICE command

The sequence of SLICE function sub-commands is the following:

Select objects to slice: (selection of the sliced 3D solids)

Specify start point of slicing plane or […] (determination of slicing plane – the simplest attempt is to use *<3points>* sub-option.

Final stage of SLICE command is to decide which part of the solid should remain or be removed:

Specify a point on desired side or [keep Both sides] <Both>:

The default sub-option value is *keep Both sides*, which results in keeping all parts of the sliced 3D Solid without removing of particular parts. Such a sliced solid can be further edited.

Section

SECTION command enables sectioning of 3D models and emerging their cross-sections. Obtained cross-sections display the inside of the 3D object (*Finkelstein, 2011*). The result of SECTION command is a 2D region according to specified plane. After sectioning the original solid lefts unmodified. Application of SECTION command is comparable to SLICE feature. The example of SECTION is presented on Fig. 2.31

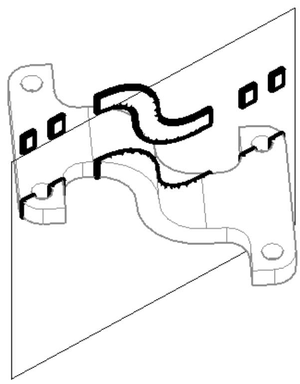

Fig. 2.31. Sectioning of the 3D solid from Fig. 2.29 using SECTION command

Fillet Edge

Fillet Edge is a very useful tool for 3D modeling in AutoCAD 2012. Command which calls this feature is FILLETEDGE or *Fillet Edge* Button on *Solid Editing* Panel. *Fillet Edge* enables to round and fillet the edges of 3D solids. The sequence of edge filleting is the following:

Select an edge or [Chain/Loop/Radius]: r (changing the filleting radius, if necessary)

Enter fillet radius or [Expression] <1.000>: 5 (new radius value)

Select an edge or [Chain/Loop/Radius]:

Press Enter to accept the fillet or [Radius]:

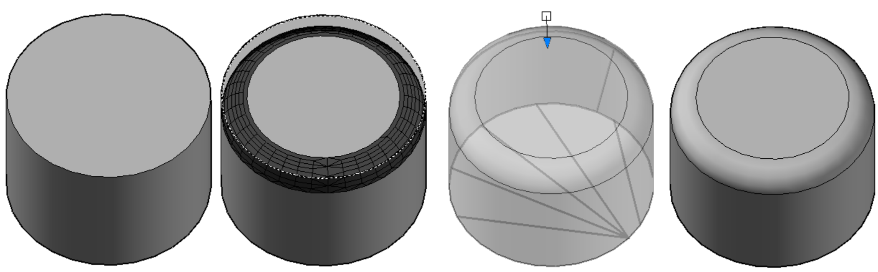

Fig. 2.32. Particular stages of FILLETEDGE command use

Chamfer Edge

Access to *Chamfer Edge* feature can be obtained by CHAMFEREDGE command or the same Button as *Fillet Edge* tool. Application of this feature is comparable to the previously mentioned one and the only difference is in the obtained solid modification, which is not rounded and the edges are cut with suitable bevel dimension (Fig. 2.33). The sequence of *Chamfer Edge* command is the following:

Select an edge or [Loop/Distance]: d (changing the bevel dimension)

Specify Distance1 or [Expression] <1.000>: 5 (1st dimension of the bevel)

Specify Distance2 or [Expression] <1.000>: 10 (2nd dimension of the bevel)

Select an edge or [Loop/Distance]:

Select another edge on the same face or [Loop/Distance]:

Press Enter to accept the chamfer or [Distance]:

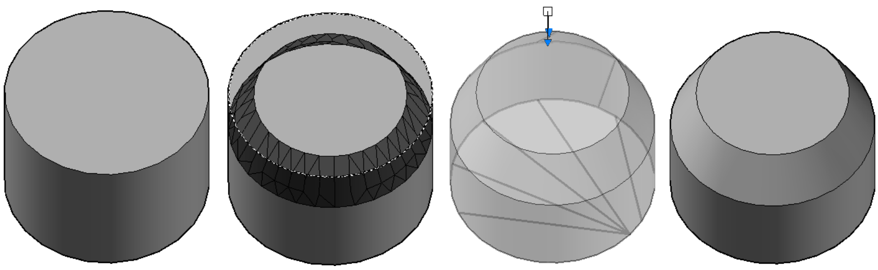

Fig. 2.33. Particular stages of CHAMFEREDGE command use

2.4.4 Other Solid Editing Functions

AutoCAD is a program which enables an extensive set of tools for edition of the modeled 3D solids. Editing tools can be divided into three main groups:

- classic tools, known from two-dimensional mode,
- 3D modeling tools (only for 3D modeling).

Classic tools are the most intuitive for all users. Despite the fact, that they were designed for 2D objects operating, they can be successfully applied for 3D modeling. Among them there are the following functions: moving, copying, mirroring etc. In *3D Modeling* interface they are clearly accessible from the main Ribbon – *Home*, *Modify* Panel. Due to their common application in 2D they will not be further presented in this part of book, anyhow their use will be widely presented in the next, chapter. Among them can be distinguished *Move*, *Copy*, *Rotate*, *Fillet*, *Chamfer*, *Scale*, *Erase*, *Offset*, *Explode*, *Mirror*.

Specialized 3D modeling tools are directly related to 3D operating. Among them there can be distinguished 3D functions being 3D variants of functions mentioned above: *3D Mirror* (MIRROR3D), *3D Move* (3DMOVE), *3D Rotate* (3DROTATE), *3D Array* (3DARRAY), *3D Scale* (3DSCALE). Application of this tools is comparable to the typical 2D functions, but described operations can be executed in space.

In general, working with the above mentioned features is quite simple but very useful. They enable quick modification of existing objects and matching them to the current conditions of the model. In most cases, the above mentioned tools are handled by *Gizmos*. *Gizmos* are user friendly AutoCAD 2012 features. In shape and color they are similar to the 3D-mode of UCS icon and can be applied for moving, rotating and scaling of 3D solids.

There are three types of *Gizmos*, which are presented in Fig. 2.34. The first *Gizmo* on the left is *Move Gizmo*, used for moving of 3D objects in the three-dimensional space (3DMOVE). Second one is *Rotate Gizmo* (3DROTATE) and the third one – *Scale Gizmo*, used for scaling of the elements (3DSCALE). Change of *Gizmo* type can be executed using *Subobject* Panel of *Home* Ribbon or using DEFAULTGIZMO command.

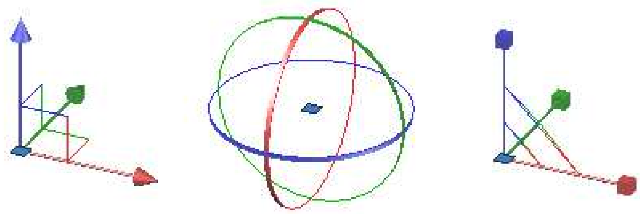

Fig. 2.34. Types of *Gizmos* available in AutoCAD 2012

To edit solids using *Gizmos* it is necessary to specify the required *Gizmo* and then show the suitable axis (moving, scaling) or rotation orbit (3DROTATE), wait until it is highlighted and modify the object.

An important feature of *Gizmos* application is the possibility of quick edition of particular parts of the complicated 3D solids. Each 3D object consists of the sub-objects like holes, insets etc. Specified hole can be quickly edited, independently on the whole solid. For that aim it should be selected in the following way – show the solid by the cursor (*don't click*) which results in information panel appearance. Press *ctrl* Button and then click the sub-solid and release *ctrl* Button. Further action is analogical to whole solids editing. The example of the described modification is presented in Fig. 2.35.

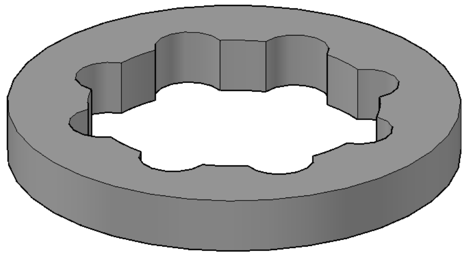

Fig. 2.35. The result of *Gizmo* application – modification of 3D solid from the Fig. 2.27

Other 3D modeling tools are placed in *Solid Editing* Panel of the *Home* Ribbon (besides UNION, SUBTRACT, INTERSECT and SLICE). Their application is widespread for solids modeling and will be shortly described in this sub-chapter. In general, most of them is called by SOLIDEDIT command and should be treated as sub-option of this command:

- *Extract Edges*, *Imprint*, *Color Edges*, *Copy Edges,*
- *Extrude Faces, Taper Faces, Move Faces, Copy Faces, Offset Faces, Delete Faces, Rotate Faces, Color Faces,*
- *Separate, Clean, Shell, Check.*

Those functions are divided into three groups. The first group is related to solid edges editing, the second one to solid faces edition, and finally, the third group is used for modification of the whole solids.

Tools from the first group are hardly ever applied in modeling of typical 3D objects. Anyhow sometimes they can be useful, for example *Extract Edges* function enables edges extraction of the solid and conversion into the wireframe model. Similar results can be obtained using *Copy Edges* function which, comparing to the previous function enables copying instead of extraction.

Second group of the SOLIDEDID functions is the most important in 3D modeling. It is focused on editing of faces, being the external shells of the described solids. It enables extrusion (*Extrude Faces, Offset Faces*), narrowing (*Taper Faces*), moving (*Move Faces*), rotation (*Rotate Faces*), copying (*Copy Faces*) of the particular faces or parts of the solids. Also there is a possibility to remove particular parts of the solids (*Delete Faces*) or change the colors of parts of the solids (*Color Faces*).

Third group of the SOLIDEDIT feature is dedicated to other operations on 3D solids, for example to separation of united 3D solids (*Separate*), converting the solids into shells (*Shell*) or checking the validity of 3D solids (*Check*), which is a useful feature, especially when drawing consists of solid and mesh models.

3 Modeling of an Example Passive House

Third chapter of the book is a practical application of 3D modeling of the single-family building. The most attractive object forms, from the point of view of Environmental Engineering are low-energy houses and passive houses (*Graham, 2003; Baker and Steemers, 2005; Nantka and Plaza, 2005*; *Feist et al., 2009*).

The idea of setting up the passive houses ecomes more and more popular, after the Energy Performance of Buildings Directive (EPBD) was introduced in 2002 (2002/91/EC). The aim of that directive was to prove energy safety in average and long-time period, protection of natural environment, Kioto protocol accomplishment, carbon dioxide emissions limitation, etc. In 2010 EPBD was novelized (recast EPBD), which required the European Union countries to elaborate plans to increase the number of zero-energy consuming buildings and consequently to produce only zero energy consuming objects after 31.12.2020. From that point of view, development of passive buildings idea becomes more important in Polish realities.

Passive house is the building characterized by very low heat energy consumption – below the level of 15kWh/(m^2·a), which could be recalculated into 1.5 of oil per square meter of living area annually (*Węglarz and Stępień, 2011*). Comparing to the typical buildings with energetic parameters over 100 kWh/(m^2·a), this value is many times lower.

Passive houses differ from classic objects with architecture, technical details of construction (funds, insulation, types of windows), but mostly the most important differences are modern installations applied. Differences between typical, energy-saving and passive houses are presented in Table 3.1.

Modeled object is supposed to fulfill all the requirements for passive house and modeling of all “passive” elements will be presented within this elaboration. The architectonical idea and the base for the proposed object is presented in the following book (*Wnuk, 2006*). This house was also presented in (*Wnuk, 2007*) and (*Piotrowski and Wnuk, 2006*). 3D model presented in this elaboration is developed basing on the assumptions of the authors of the cited book above, but many details and modifications were added and proposed by the authors of this book.

Modeled passive is supposed to be fund on a reinforced concrete slab with attic above the ground floor. Communication between particular floors (ground floor and the attic) will be provided by the staircase. It is not planned to use balconies, dormer windows, skylights, basement and chimneys. Characteristic elements of the designed object will be the following – fund construction, ventilation-heating system, sanitary systems (cold water, hot water, sewage system, rainwater system) etc.

Projections of the ground floor and the attic of the modeled building are presented in Fig. 3.1. and 3.2.

Table 3.1. Comparison of particular features of typical buildings with energy-saving and passive houses (*Węglarz and Stępień, 2011*)

Type of building	Fulfilling actual requirements	Energy-saving	Passive
Width of insulation layer of external walls	About12cm	About18cm	About 30cm of traditional insulation
Heat transfer coefficient "U" of external barriers	0.3 [W/(m^2·K)]	Up to 0.2 [W/(m^2·K)]	Up to 0.1 (0.15) [W/(m^2·K)]
Width of insulation layer of roof	About16cm	About 30cm of traditional insulation	About 40cm of traditional insulation
Windows distribution	No regulations	Mainly at southern elevation (suitable protection for extensive insolation should be provided)	Mainly at southern elevation (suitable protection for extensive insolation should be provided) Limitation of roof windows
Heat transfer coefficient "U" of windows	Up to 1.8 [W/(m^2·K)]	1.8–1.3 [W/(m^2·K)]	Up to 0.8 [W/(m^2·K)]
Balcony construction	Traditional (slab connected to the ceiling)	With elements isolating the wall or balconies with own construction	No balconies or balconies on their own construction (independent on the external wall)
Ventilation system	Natural, gravitational ventilation	Hybrid ventilation or mechanical ventilation with heat recovery	Mechanical ventilation with heat recovery and ground heat exchanger
Heating system	Traditional	Low-temperature heating system	In principle – no typical heating system Only extra heating for ventilation air or supplementary electric heaters)
Utilisation of solar energy	No utilization	Solar collectors in hot water systems	Solar collectors in hot water systems
Annular energy consumption for heating	90–120 [kWh(m^2·a)]	30–70 [kWh(m^2·a)]	Up to 15 [kWh(m^2·a)]

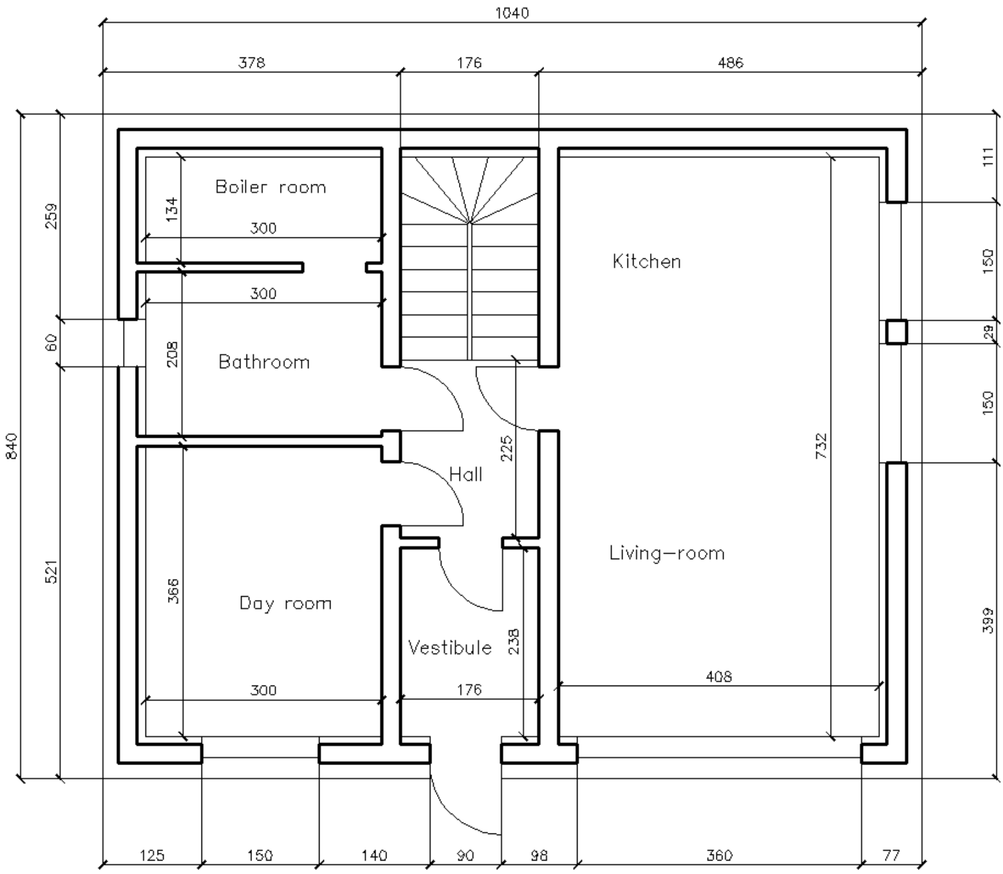

Fig. 3.1. Projection of ground floor

The proposed object will be set on insulated reinforced concrete slab with two layers of insulation. External walls will be made of low density aerated concrete 24cm thick. Aerated concrete is a suitable material for energy saving objects due to its structure and thermal parameters (*Narayanan and Ramamurthy, 2000; Roels et al., 2002; Siejko and Babiński, 2005; Scheffler and Colombo, 2005*). Main feature of this material is low heat conductivity coefficient λ that equals 0.1[W/(m·K)]. Another advantage of this material is high leak tightness and possibility of thin mortars application, which is strongly advantageous in case of energy-saving and passive houses. To obtain possibly low values of heat transfer coefficient "U", external barriers are insulated from both sides – external and internal one, which is not typical in traditional building. Construction of roof is the following: traditional rafters covered with OSB Board and steel sheet. Insulation layer – mineral wool 30cm.

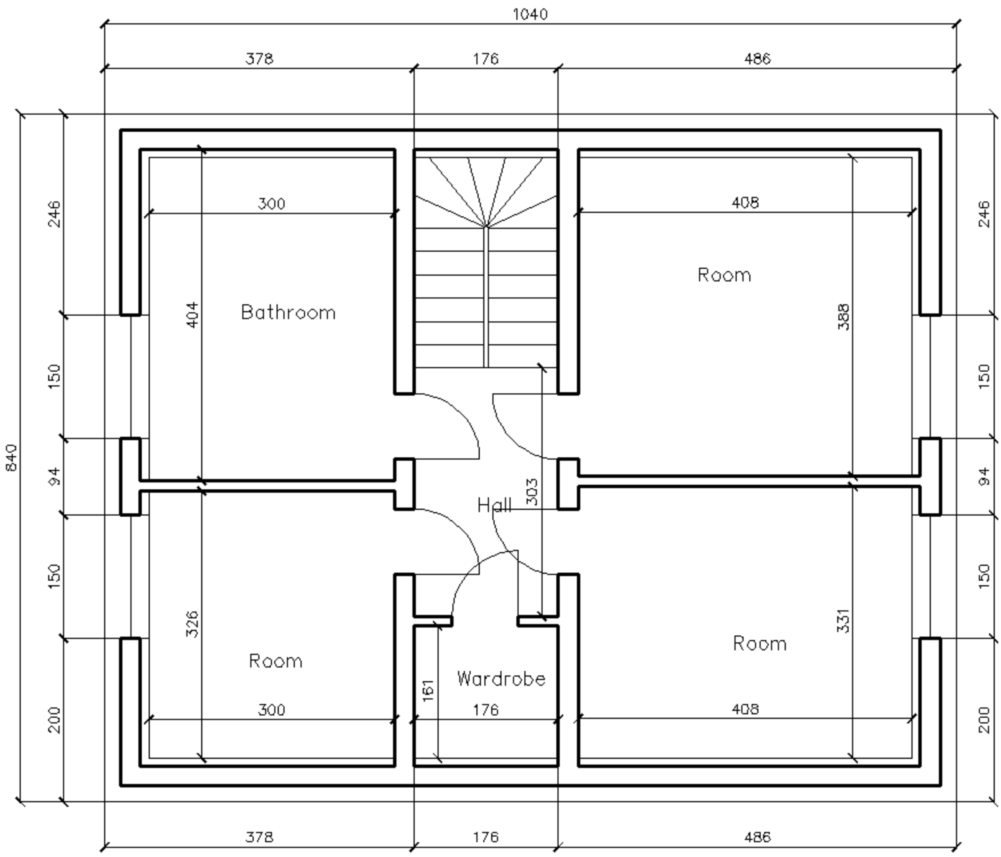

Fig. 3.2. Projection of the attic

3.1 Funds

According to (*Wnuk, 2006*), the most effective fund construction for the passive house is slab of reinforced concrete with insulation (Fig. 3.3). Proposed construction of the fund will be the following:

- all-in aggregate,
- water-proof layer (insulating foil),
- mineral wool (for floors, 18cm thick),
- reinforced concrete slab (20cm)
- water-proof layer,
- mineral wool (18cm thick),
- concrete layer (10cm),
- flooring (wood flooring, tiles).

For that aim the following layers were created: *Ground*, *ConcreteSlab*, *MineralWool*, *LightConcrete*, *Tiles*, *Parquet*. Water proof layers will be omitted in this model, because they are very thin and their absence will not influence the whole construction from the visual point of view. Anyhow it must be underlined here that their application in the described construction is very important from the point of view of water-heat processes.

The dimensions of all-in aggregate, represented by the *Ground* layer is not important for the whole model and will be default, minimally exceeding the projection dimensions of the building (it may be modified in further part of the whole process of building modeling). It may be generated using BOX command and giving the necessary dimensions, for example 1500,1500,50 (assuming that the operating units are centimeters). Second layer of the slab is insulating mineral wool. It can be also generated using BOX command. The dimensions of that layer should fit the object projection dimensions (1000×800cm) and thickness of the discussed layer is 18cm according to previous assumptions, so to point out the second corner of the box, the following relative coordinates should be input: @1000,800,18.

Thickness of reinforced concrete (*ConcreteSlab*) slab is assumed to be 20cm, that's why during using BOX command, the following relative coordinates should be given@1000,800,20. Next layer of insulating material (*MineralWool*) can be copied above the plate using the typical 2D command – COPY. The same is with concrete layer. Final floor layer may be different, depending on type of room (Parquet or Tiles) and will be added to after the ground floor is finished.

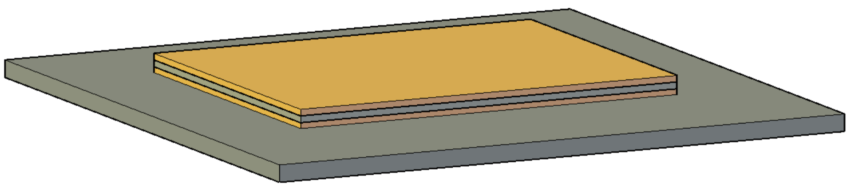

Fig. 3.3. Funds of modeled building

3.2 External walls

As it was mentioned in Chapter 3.1, the construction of external barriers will be based on low density aerated concrete and thermal insulation will be mineral wool attached from both sides of the construction. To model such a barrier it is necessary to define at least two layers in AutoCAD program – *AeratedConcrete* and *MineralWoolWalls*. The layers for the external and internal plasters do not have to be assigned. This is mainly caused by their low thickness, so they can be avoided in the presented model. Anyhow it will be possible to project their presence using suitable materials during rendering procedure.

Assumed height of the room is 2.70m (2.50m + 0.2m for suspended ceiling), so it is possible to generate external wall of aerated concrete using POLYSOLID function with the following parameters: *Height*=270, *Width*=24 (thickness of aerated concrete block) and *Justification* = Left (or Right depending of drawing direction). In case of any problems of using of the POLYSOLID feature, it is possible to use a set of boxes or other possible solids. At this stage of working, the example object may look as presented at Fig. 3.4.

Assumed height of the room is 2.70m (2.50 + 0.2m for suspended ceiling it is possible to generate external wall with aerated concrete using POLYSOLID function with the following parameters: Height=270, Width=24 (thickness of aerated concrete block) and Justification = Left (or Right depending of drawing direction) and using Object Snap aids draw the wall along the perimeter of the plate. In case of problems of working with POLYSOLID it is possible to use a set of boxes or other solid objects. At this level of working the example object may look as presented at Fig. 3.4.

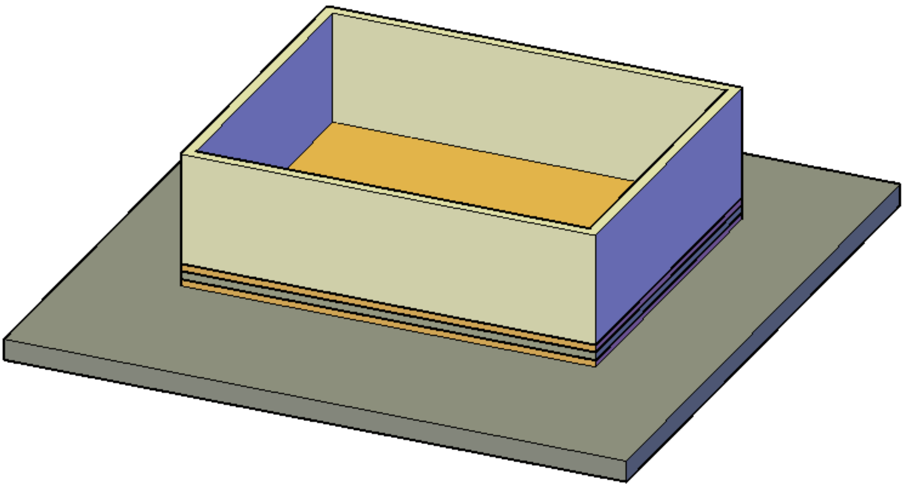

Fig. 3.4. Concrete plate with aerated concrete external barrier

The most important constructional elements of passive house's external barriers are insulation layers. Drawing of insulation is also possible using POLYSOLID function. It requires to select a suitable layer from the list (*MineralWoolWalls*) and to draw the suitable polysolids with the following widths: 20cm external layer and 10cm the internal one. Fig. 3.5 represents the modeled object at this stage of working. It is visible that building external envelope has no suitable gaps for windows and door, but they can steel be inserted in later stages, using SUBTRACT function.

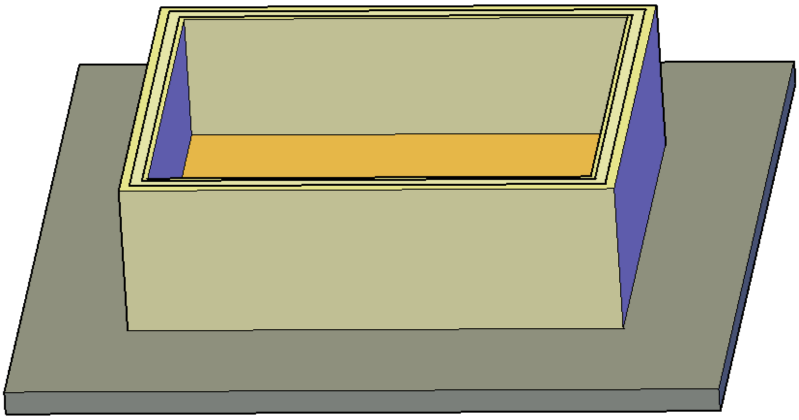

Fig. 3.5. External barriers of modeled object

3.3 *Internal walls*

There are no special requirements for internal walls construction in passive houses technology. They do not have to be insulated, the applied materials may be the same as main material used for external envelopes – aerated concrete, that's why it is not necessary to establish new layer for the internal barriers. It can be simply assumed that load-bearing walls are 24cm wide and other walls are 12cm wide. In opinion of the authors, the simplest and the most effective it will be to apply BOX command to form the internal barriers. Distribution of rooms and walls in ground floor level is prepared according to Fig. 3.1 and is presented in 3D model in Fig. 3.6 and Fig. 3.7.

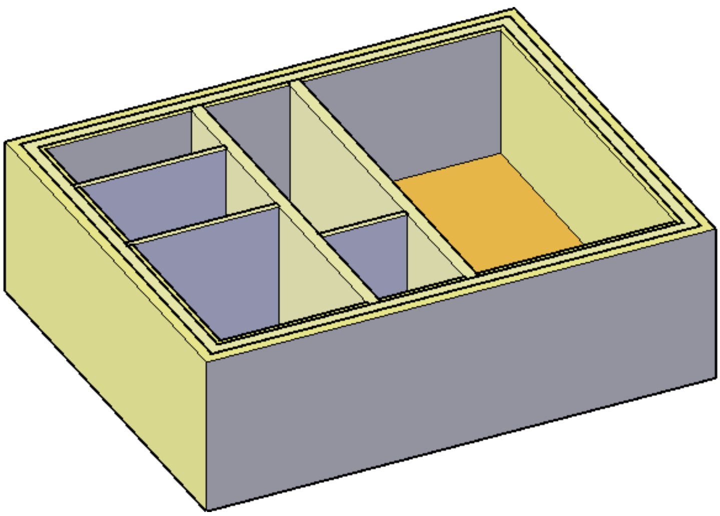

Fig. 3.6. Isometric view of modeled building

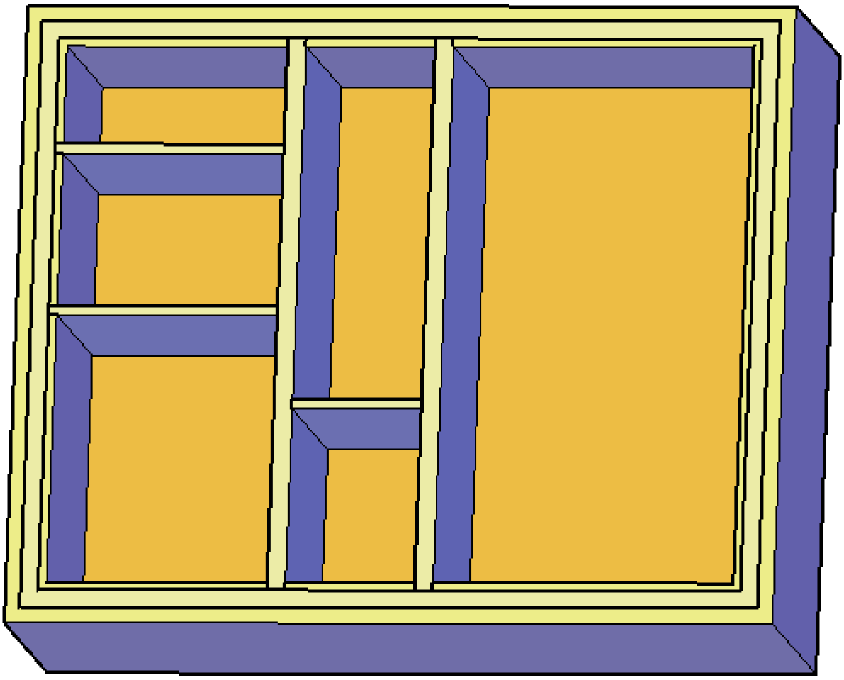

Fig. 3.7. Projection (top view with gentle deviation) of modeled building showing room and internal walls distribution

An interesting detail is presented on Fig. 3.8 – connection of internal wall with the external wall, where internal walls join the external envelopes. This required to remove some part of the internal insulation material. For that aim SLICE command was used and parts of the material were deleted. After the material (*MineralWoolWalls*) was removed, the walls were extruded to touch the external barrier. For that aim SOLIDEDIT function was used with *Extrude Faces* sub-option (*Solid Editing* Panel on *Home* and *Solid* Ribbon).

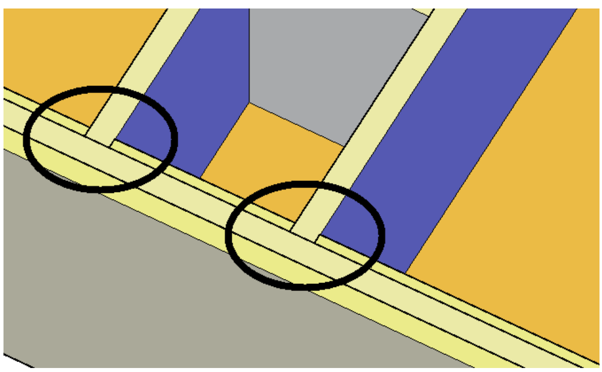

Fig. 3.8. Detail of connection between internal and the external wall

3.4 Door and window gaps

Next step of building modeling will be preparation of gaps for internal and external door and windows in the ground floor. The most effective will be to use SUBTRACT function. It can be assumed, that internal door's dimension is 80x210cm, external door's dimension is 90x210cm. Windows dimension is 150x150cm and terrace window dimension 180x250cm.

It seems the most efficient to generate boxes that will be inserted into the walls, in suitable positions, which after the subtraction will form the suitable gaps. This is presented at Fig. 3.9.

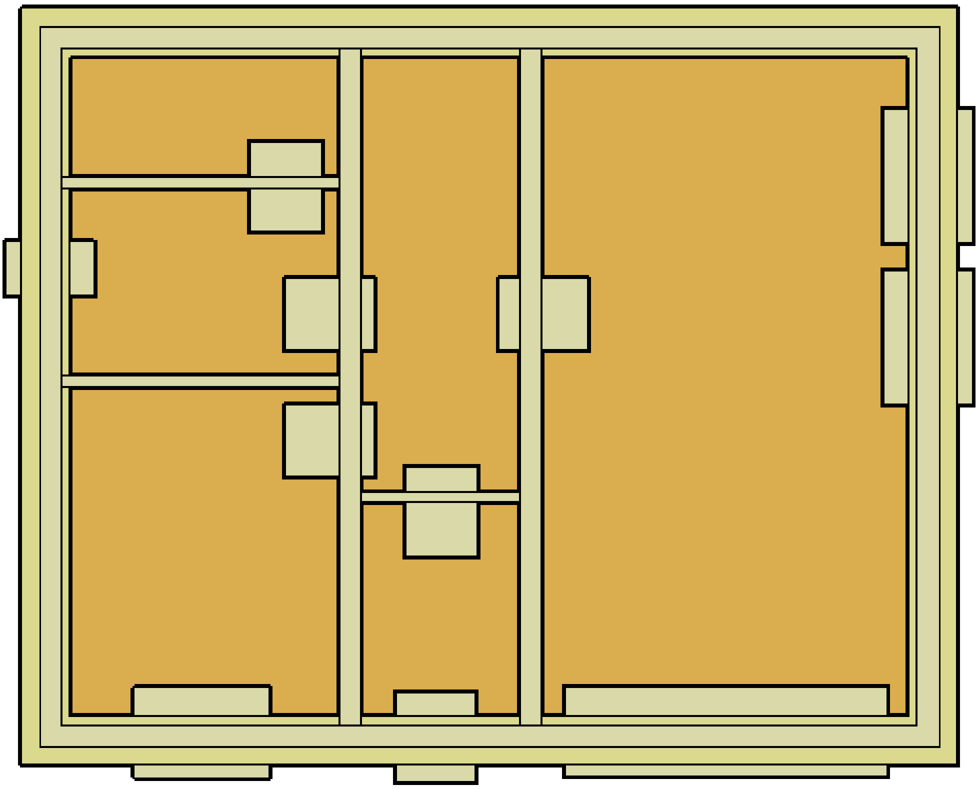

Fig. 3.9. Projection of the building with prepared cuboids necessary to create windows and door gaps

Width of each cuboid is not important at this stage, because finally they will be removed during subtraction. The cuboids ought to be inserted into the barriers in the suitable positions. Result of subtraction process is presented at Fig. 3.10 and Fig. 3.11. It must be underlined that in case of the external barriers the subtraction should be executed in three separate stages (separate the gap for each layer), otherwise layered structure of the external envelopes would be lost (Fig. 3.11).

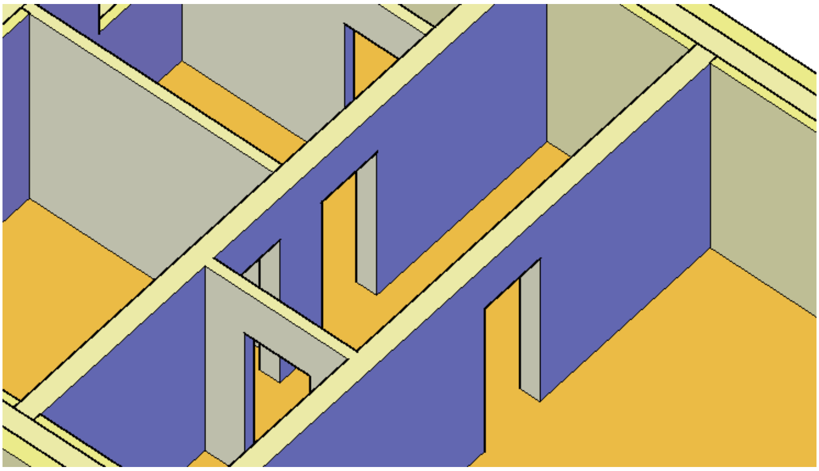

Fig. 3.10. Openings for internal doors

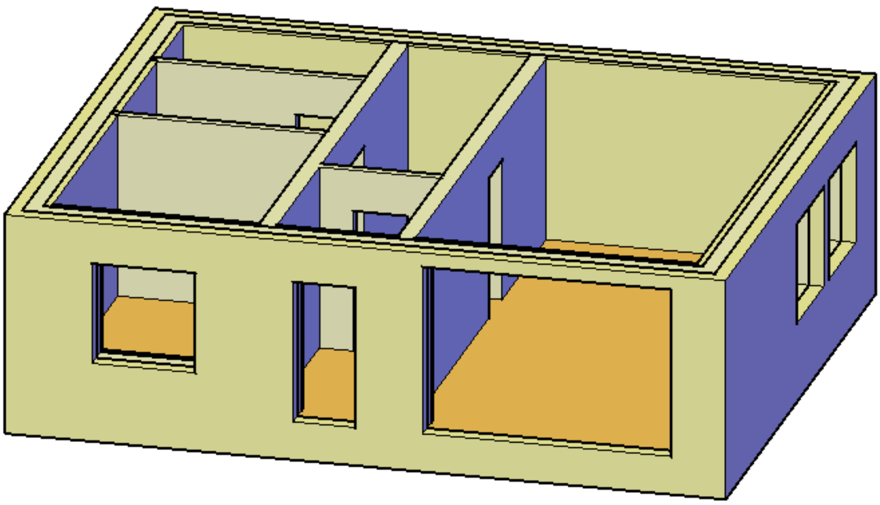

Fig. 3.11. Openings for doors and windows in the whole ground floor

3.5 Ceilings

The next stage of described passive house accomplishment will be modeling of the ceiling above the ground floor. From the point of view of energetic parameters construction of ceiling between particular floors is not important and the detailed modeling of each elements is will not be presented. The pressure will be put on the most important layers of the construction. In practice the most important challenge is suitable construction of the ring beam and the suitable insulating layer. Example construction of proposed ceiling is presented in Fig. 3.12 (*Wnuk, 2006*).

According to (*Wnuk*, *2006*) the ceiling construction is the following (from below):

- suspended ceiling (with construction),
- I-profile, wooden beam (35cm) with heat-acoustic insulation (mineral wool),
- OSB Boards (Oriented Strand Boards),
- special undercoat,
- desks or tiles.

To simplify the construction in the modeled object the following layers will be created: *SuspCeiling*, *CeilingConstruction*, *CeilingFloor*. Also it is necessary to create a suitable layer for the ring beam (*RingBeam*).

The first stage of ceiling modeling is formation of the ring beam. It may be realized by generating the cuboids with the following dimensions: height – 35cm (height of beams), width – aerated concreted width (24cm), length – length of the wall. After the suitable cuboids are created, they should be summed using UNION command, to form the construction presented at Fig. 3.12. Also it is suggested here to extend the load-bearing internal walls to protrude out of the ceiling layers. Temporary extrusion height can be established for 50cm, and may be changed during modeling of the attic construction. It could be easily realized using SOLIDEDIT sub-function – *Extrude Faces*, which is available at *Solid Editing* Panel. According to previous assumptions the extrusion height is 50cm.

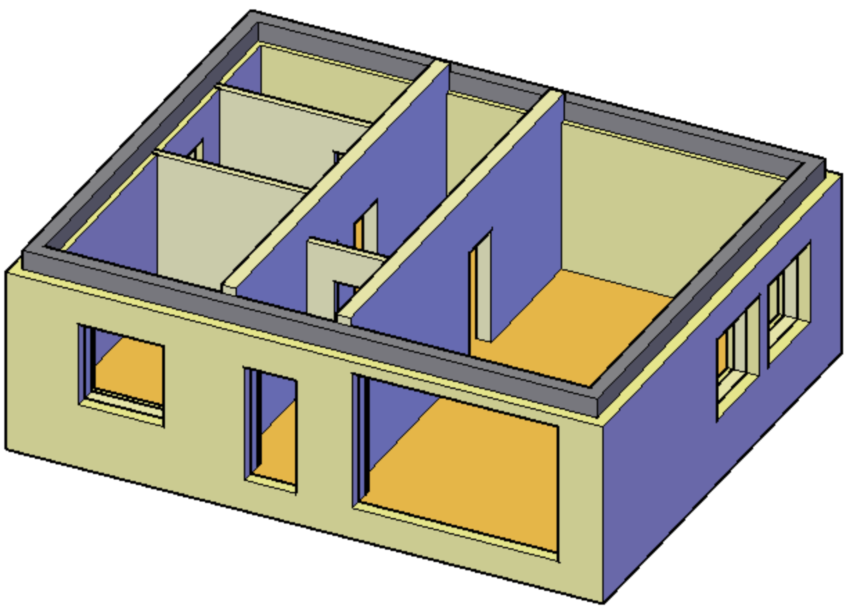

Fig. 3.12. First floor of the modeled building with ring beam visible and extruded load-bearing internal walls

The next step is ceiling construction. To generate this significant element it is necessary to select *CeilingConstruction* layer and generate cuboids using BOX command. The obtained result is presented on Fig. 3.13.

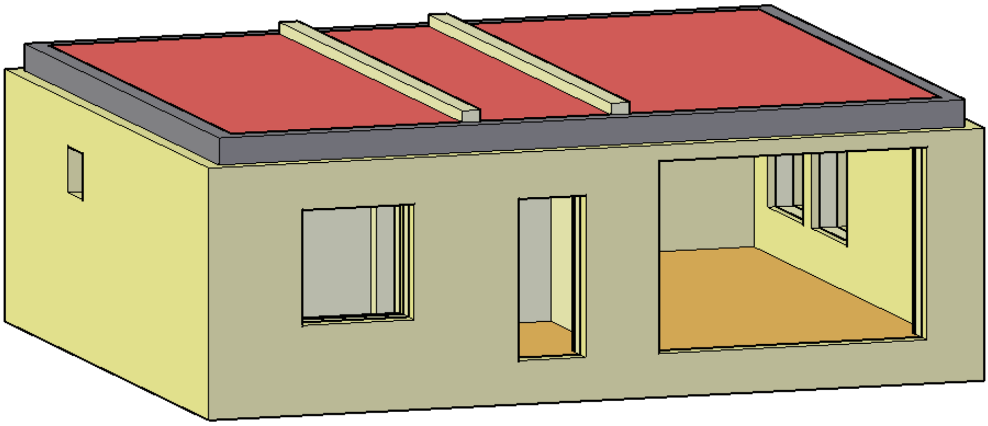

Fig. 3.13. First floor of modeled house with ceiling construction visible

To finalize the details of the ceiling construction, final layer is required which will represent the tiles of other finishing elements. This layer would cover the ceiling construction. It may be obtained in several ways, for example by boxes formation with suitable height (5cm for example) and areas similar to ceiling construction. Another problem is to create the suspended ceiling. It is of the same dimensions as ceiling construction, but placed 10cm below it. This may cause several problems to generate the suitable model of this element. The easiest way to obtain the described result is to turn off the layers considered with external barriers (*AeratedConcrete*, *MineralWoolWalls*) and previously generated *CeilingFloor* layer. Since then, it should be relatively easy to obtain the construction of the suspended ceiling (without its construction elements like mountings, grips etc.). It is suggested to copy the *CeilingConstruction* elements below, change the layer of that elements using the list in Layers *Panel* into *SuspCeiling*. The width of this elements can be simplified to 2cm (thickness of typical gypsum board is about 1.25cm plus eventual plaster layer). Considering that passive house is heated with warm air from ventilation system, it is strongly recommended to leave at least 15cm of air gap between the ceiling construction and the suspended ceiling to obtain enough space for installation (especially ventilation ducts). Simplified construction of such a described ceiling is presented at Fig. 3.14.

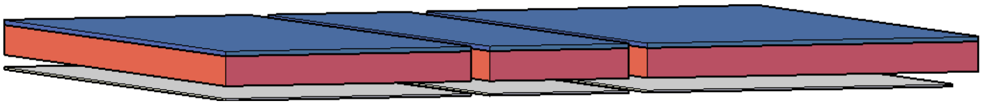

Fig. 3.14. Construction of ceiling of the modeled passive house (external barrier and ring beam layers are turned off)

After all, it should be reminded, that suspended ceiling boards are separately used in each room, so in case of nonbearing walls, they should also be cut (Fig. 3.15). This could be done using SLICE command. This attempt may be difficult to be done, to make it easier it is possible to switch visual style into 3D Wireframe Mode – it would show some hidden walls which would be used for definition of slicing planes.

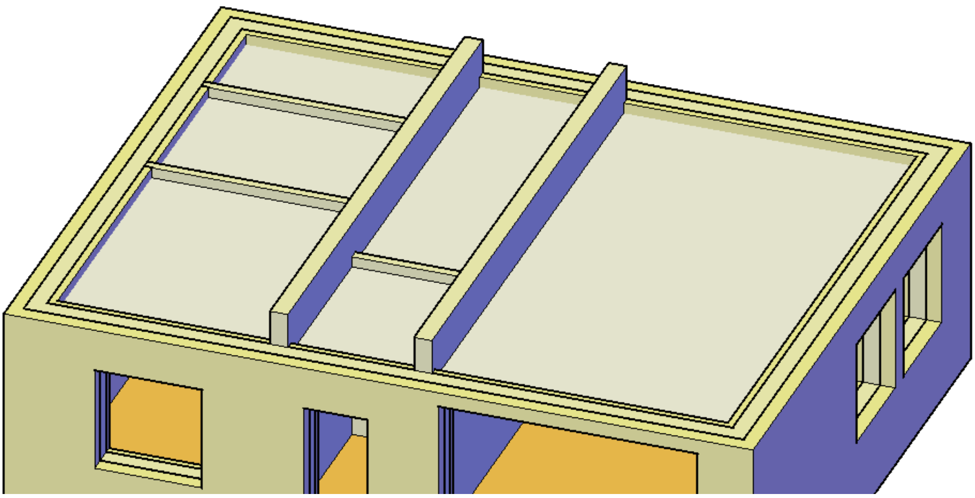

Fig. 3.15. Suspended ceiling over the ground floor

3.6 Knee walls construction

According to the design assumptions, top of the modeled building will be the attic. To increase the functionality of it, it would be suggested to use the knee wall, which would significantly increase its capacity.

It could be assumed that knee wall will be 100cm high and put on the ring beam. Above it next ring beam would be required which will be the base construction for the roof details. To obtain this, it is suggested to redraw cuboids (using BOX command) around the ring beam. Height of the mentioned cuboids is 100cm, layer – *AeratedConcrete*. After the cuboids are generated, they could be united using UNION command. And the ring beam for the roof construction can be recopied at the top of the knee wall. The obtained result is presented at Fig. 3.16.

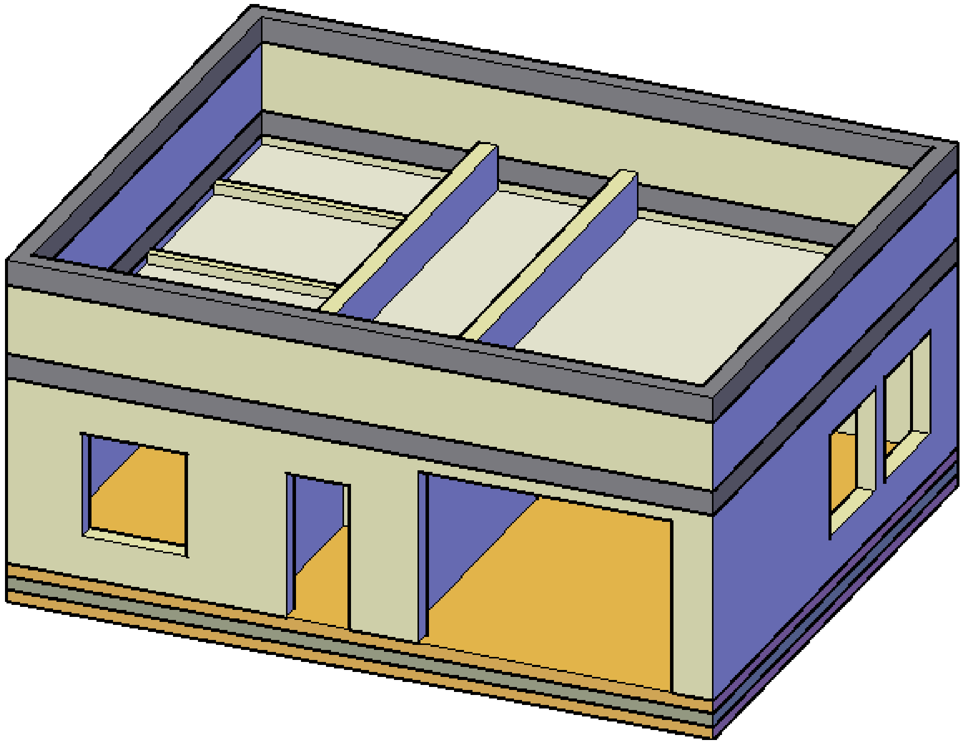

Fig. 3.16. Knee wall with the ring beam ready for the roof construction

After this stage is finished, it is possible to fill up the missing part of mineral wool insulation in the top part of the external walls. It is possible to be done using *Solid Editing* subcommand *Extrude Faces* for the distance of 170cm (difference between top of the upper ring beam and the top of the existing insulation).

3.7 Stairs

To generate the staircase model, finishing of floor should be established in detail, because the dimensions of the stairs will strongly depend on the difference of levels between the two floors. For that aim, all layers have been generated – both floor finishing in ground floor and the attic. After all the layers had been generated, the distance according to *Z* (height) axis was measured using DIST command. For the discussed house, the difference in levels is 308cm.

Due to small dimensions of the staircase it is planned to design winder stairs with dimensions of each step 16.21 x 28.5. Such designed stairs fulfill the ergonomic rule of 2h+s, which means that doubled riser dimension plus tread equals step length. In this particular case it is 60.92 which means that such designed stairs will be comfortable for the users. Hollow newel dimension in the planed staircase will be 5cm and flight of stairs width 85.5cm, which directly depends on hall width.

To generate the stairs it is suggested to create a new *Stairs* layer with necessary color and draw the projection of the described system, keeping the right dimensions (Fig. 3.17). No constructional details will be considered in this model, only dimensions will count.

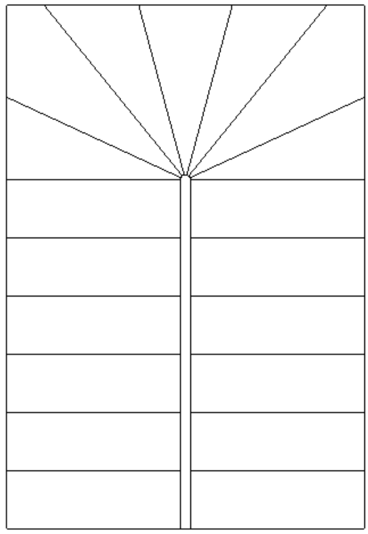

Fig. 3.17. 2D projection of stairs with proper dimensions

The simplest solution for the stairs generation is to form the particular stair steps into the closed polylines (using PEDIT function), extrude the closed polylines for the distance of 16.21cm (riser dimension) and them set them in proper shape presented at Fig. 3.18.

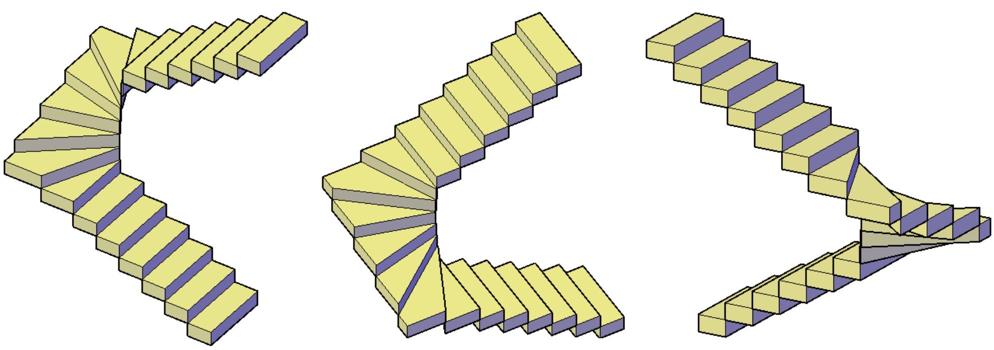

Fig. 3.18. Various views of obtained stairs

It should be not forgotten to prepare special gaps for the staircase, which can be easily obtained using *Solid Editing – Extrude Faces* function. The result of this is visible on Fig. 3.19.

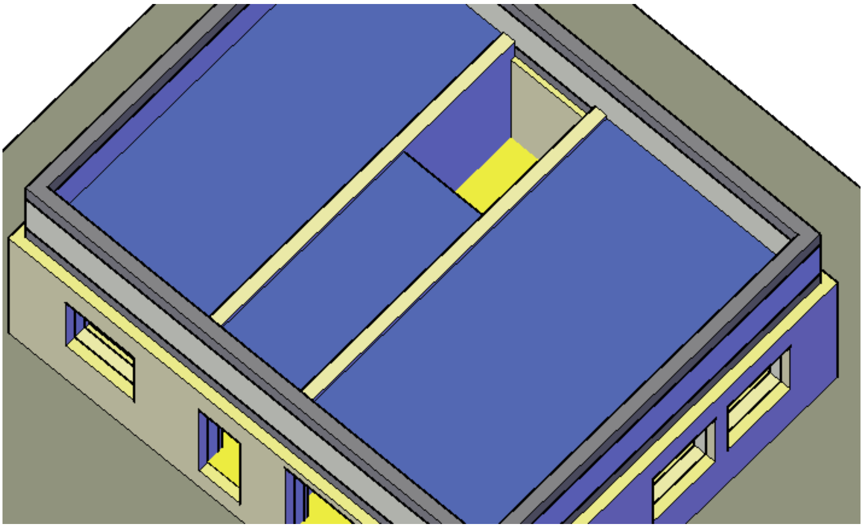

Fig. 3.19. View of the top floor with the gap prepared for the staircase

After all the stairs are ready, they should be placed in the right position of the house, which is presented at Fig. 3.20. Also, it is important to add the barrier which will be presented in the later part of this chapter.

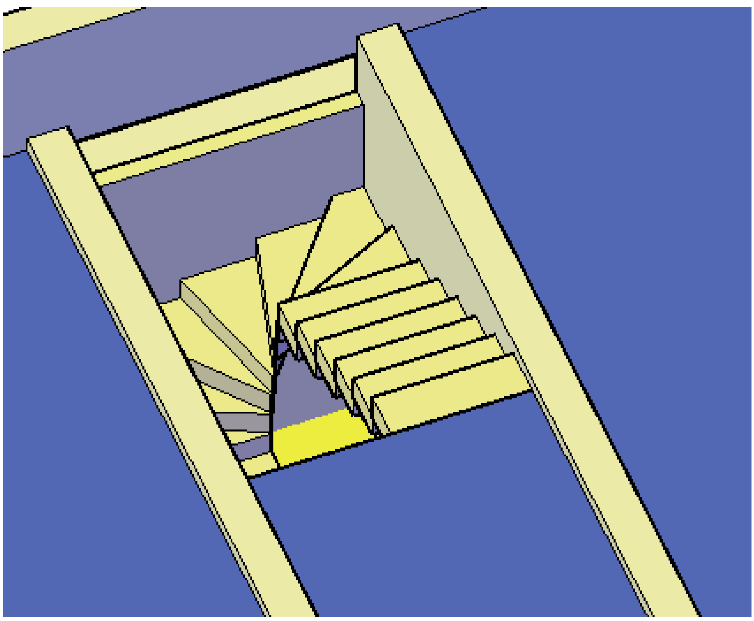

Fig. 3.20. View of the staircase

3.8 Roof construction

Next, very important stage of constructing the passive building is to prepare the roof construction. It is assumed that building top will be the traditional wooden, rafter roof construction. Passive house presented in (*Wnuk, 2006*) is equipped with construction made of I-profile wooden beams, but here it is more interesting to demonstrate the typical beams, with rectangular cross-section. Roof covering is planned as galvanized metal sheet, which is not important at this stage of object designing and will be important during rendering procedure, which will be in detail described in the final part of this monograph.

To obtain the greatest functionality of the designed attic it is planned to apply the simplest construction of the roof, which will not disturb to distribute the particular rooms. Width of the house measured according to the external walls is 800cm, which means that the simplest and most efficient solution will be collar beam roof construction without posts (*Markiewicz, 2006*). This type of construction is available for objects which are 7–12 meters wide and will be suitable for this house. According to Markiewicz (2006), minimal suggested angle of rafters inclination is 35°. Also, it should be remembered, that placing the collar beam at the level 2.6–2.7m above the floor, would make it a right support for the ceiling construction over the attic, which will be presented later..

It is assumed that roof inclination is 45°. According to the passive house standards, it seems reasonable to apply the beams with significant vertical dimension in their cross section. It will improve their mechanical parameters (increase the moment of inertia) but also will generate enough space for roof thermal insulation (placed between the rafters). For further works it is assumed the following dimension of the rafters cross-section – 10×24cm. Rafters will be put on wall plate which are attached to the ring beams. In our model, we avoid the details of wall plates attachment to the ring beams and details of particular beams connection, because they seem not important from the point of view of this elaboration, which is mainly focused on “passive”, not constructional details.

First stage of roof construction modeling is modeling of the wall plates. The cross section of this element is traditionally 10×10cm. In this case it is suggested to increase the dimension of this element, especially due to increased dimensions of the rafters. It can be for example 15×15cm. Length of each wall plate is the same as building length. To draw this element it is suggested to create a new layer *RoofConstruction* for example and draw a square 15×15 parallel to the shorter external wall. Then the square can be extruded for 952cm, which is the length of the ring beam without two walls. After the wall plate is generated, it should be attached to ring beam and copied to the other side of the building. Fig. 3.21 presents the described construction.

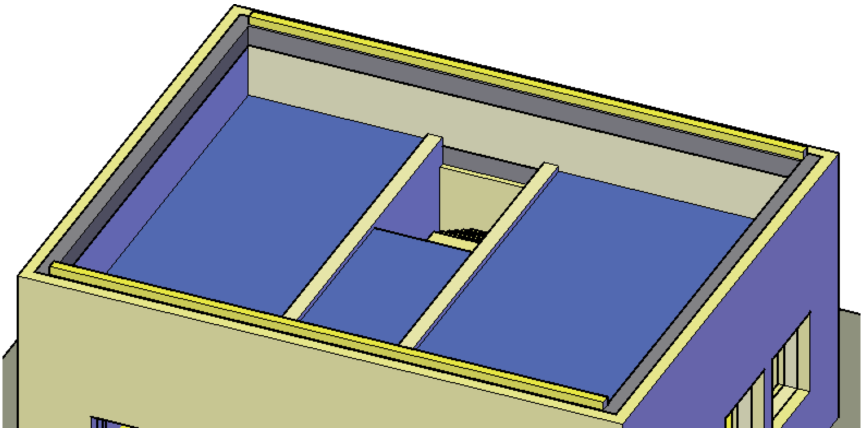

Fig. 3.21. Modeled object with wall plate attached at ring beam ready to put the roof construction

Next step is modeling of the rafters. For that aim, the most efficient it would be to rotate the building projection into the parallel direction, to left or right gable wall, using *ViewCube* or other navigation features. Then change the coordinate system into the user coordinate system, compatible to the current projection (UCS – VIEW). Then draw a long line at the angle of 45°. Length of the line is not important – it will be trimmed during further procedures. This will be the first line of the rafter. Next line can be generated using OFFSET function with offset distance equal to 24cm (height of the rafter). Such a prepared set should be put into the wall projection at the suitable position, presented at Fig. 3.22. Next step is preparation of a drawing aid for MIRROR function. It will be the symmetric axis of the building side projection (Fig. 3.22) and it will help to generate the second rafter, symmetric to the first one. It is strongly recommended to keep the flat drawing details (lines) in a common plane. If any of the visible lines would be drawn in different plane, the rafter would not be generated.

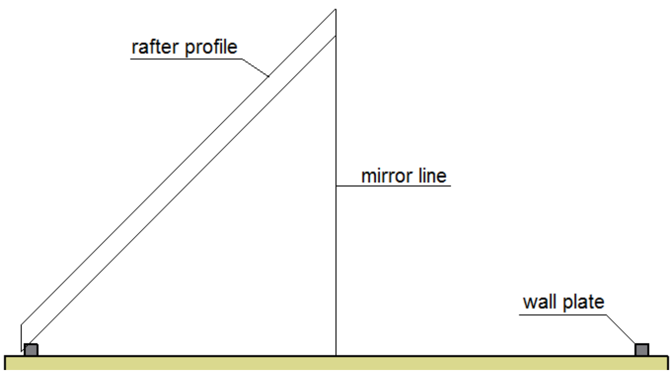

Fig. 3.22. Part of the wall with prepared contours of the rafter

After this, the second rafter can be generated using MIRROR function. When the described set rafters is generated, collar beam should be modeled, which may be obtained by simple drawing of the suitable shape in the right position and height. It is suggested to draw it 270cm above the top of the attic floor, would enable to use collar beam for the ceiling construction. OFFSET distance maybe also 24cm long, which would mean a lot of space for insulation. After all, the cross section of the rafters is almost ready. To finalize this stage, the unnecessary lines should be cut using TRIM function and the whole construction united into single, closed polyline, using JOIN function. In this way two polylines would be generated – internal triangle, and external contour of the rafters. Obtained result is presented at Fig. 3.23. After the closed polylines are ready, it is possible to extrude them into the realistic rafters. System of rafters ready to use is presented at Fig. 3.24. In this case extrusion would run in the following stages:

- extrusion of the internal triangle for the distance more than 24cm,
- extrusion of the rafters for the distance of 24cm (width of the rafters),
- subtraction of the internal triangle using SUBTRACT command.

Otherwise it is possible to use PRESSPULL command to obtain the comparable result.

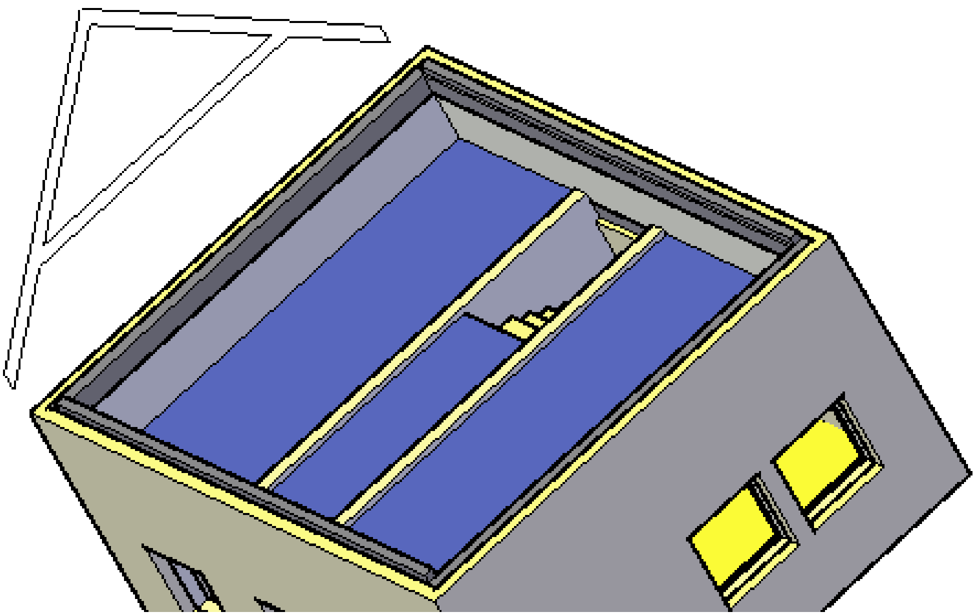

Fig. 3.23. Cross section of rafters before they are extruded

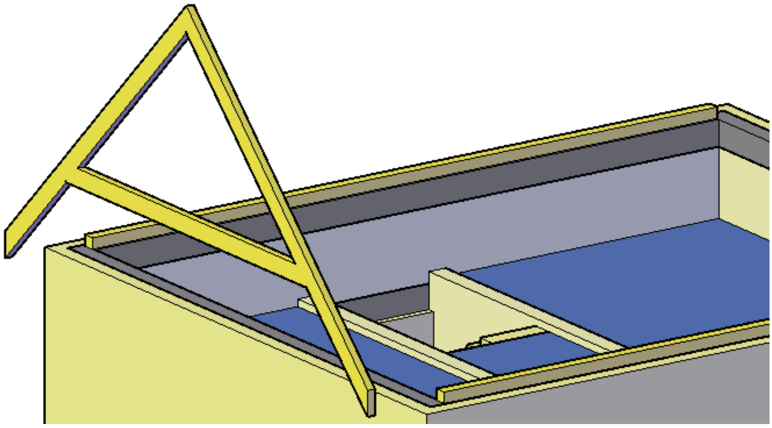

Fig. 3.24. Extruded rafters before attachment to the wall plates

To get the full construction of the rafters it is required to put the first rafters directly at the beginning of the wall plate edge and use ARRAY function. It can be a typical 2D ARRAY function which unfortunately, in AutoCAD2012 is not supported by the *Array Dialog Window*, and maybe difficult to be used. Anyhow, there should be selected *Rectangular Array* option and the distance between the elements set for 118cm (distribution of the rafters). The obtained results are presented at below figures.

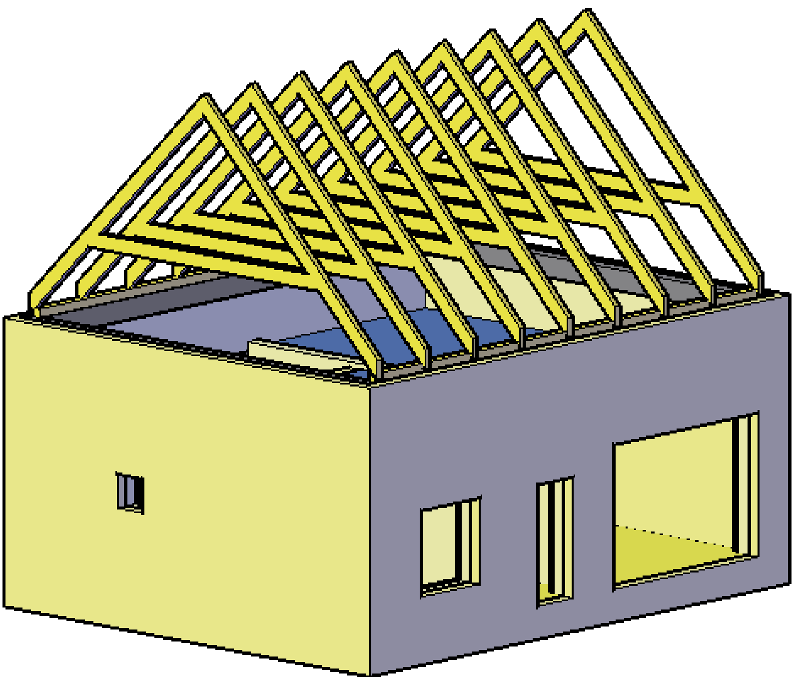

Fig. 3.25. Rafters construction of the modeled passive house

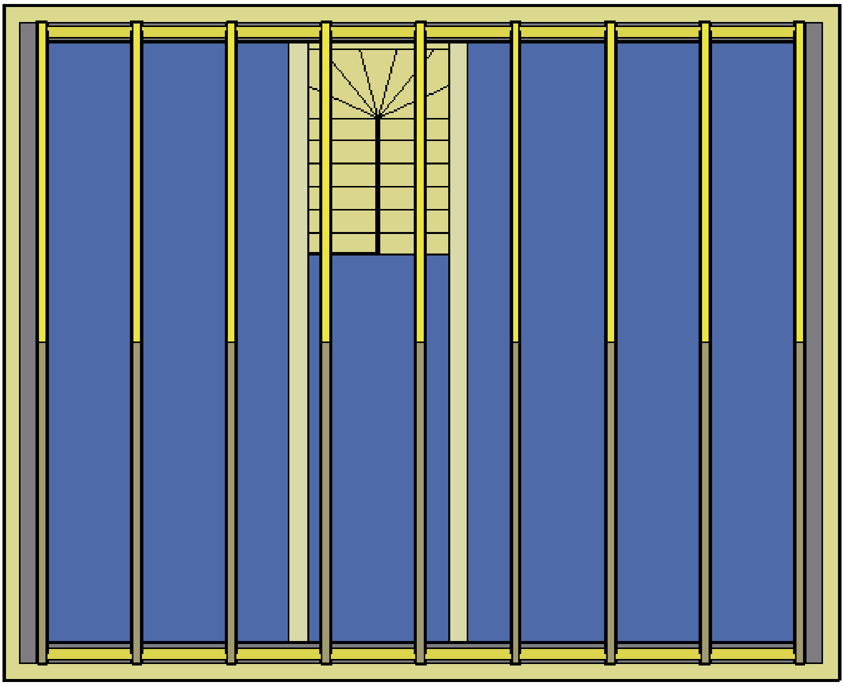

Fig. 3.26. Projection of the modeled house with visible rafters distribution

After the rafters construction is finished, there should be prepared the base for roof covering and increasing the strength of the construction. Traditionally, wooden roof battens are applied, which are the desks about 4x5cm of cross-section, joining all rafters together. According to (*Wnuk, 2006*) for passive houses could be successfully applied Oriented Strand Boards, which would support sufficient stiffness of the whole construction.

To lay the OSB boards on the rafters, it seems reasonable to change the coordinate system into the temporary system, fitting the roof slope. For that aim UCS command should be used and new coordinate system should be set as presented at Fig. 3.27.

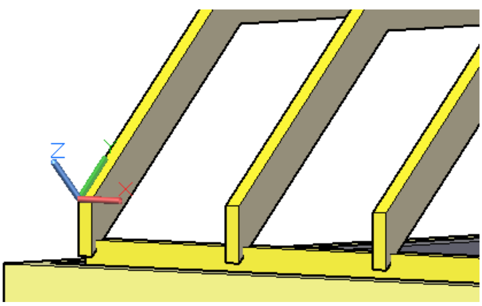

Fig. 3.27. Setting the User Coordinate System according to rafters slope

After the user coordinate system is defined, it is possible to draw the OSB board. For that aim the suitable layer should be created and the OSB board could be generated using BOX command or extruding the rectangle. Other side can be covered using MIRROR function according to axis of the house symmetry. The obtained result is presented at Fig. 3.28.

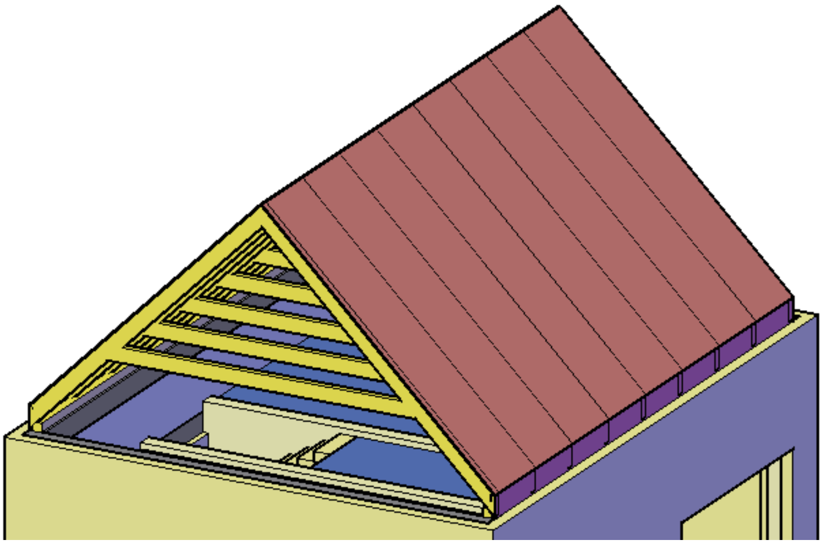

Fig. 3.28. Roof construction covered using OSB (Oriented Strand Boards)

It must be remembered that construction is not finished yet. It still needs to be covered with roof covering, as it was established before – steel sheet. For that aim the new layer (*RoofCover*) should be created, and new objects should be put on the OSB board. This can be done using simple BOX command or copying the OSB board objects above and changing their layer property into *RoofCover*.

After the roof cover is put onto the whole construction, it seems necessary to put insulation layer into the construction. According to (*Wnuk, 2006*) it is assumed to use at least 30cm of Mineral Wool. One layer will be put between the rafters and collar beams, another one will be put below that construction. Such solution will minimize the possibility of thermal bridges presence in such a construction. Below mineral wool layer gypsum boards will be mounted. For that aim two, new layers should be created: *MineralWoolRoof* and *GypsumBoard*. To make work easier it is suggested to turn off temporally layers connected with OSB boards and roof cover and then, place suitable number of boxes between the rafters and the collar beams. Otherwise it is possible to draw a cross-section of the mineral wool layer and extrude it to the required width. The decision how to generate this element should be made by the reader himself. Current status of the roof construction modeling is presented on Fig. 3.29.

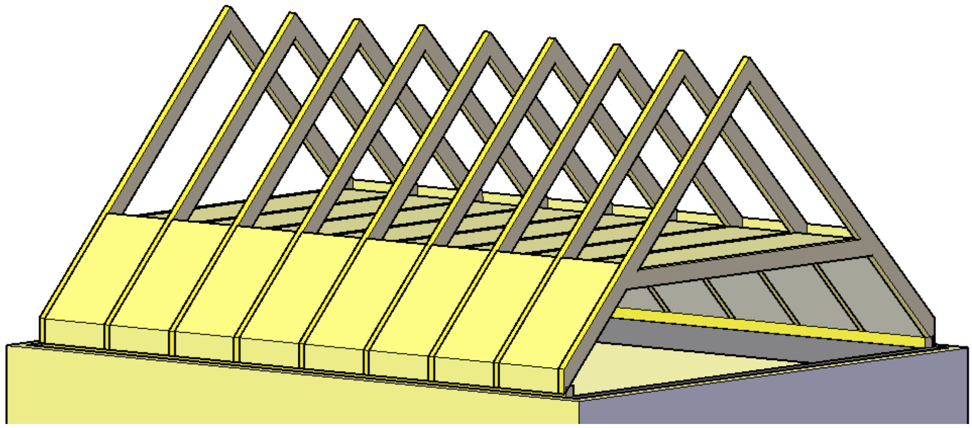

Fig. 3.29. Roof construction with insulation layer

Next stage of work is covering the internal part of the rafters with another 10cm layer of mineral wool and then gypsum boards. This requires to fit the necessary objects to the rafters and insulation boards. The result of works at current stage is presented below.

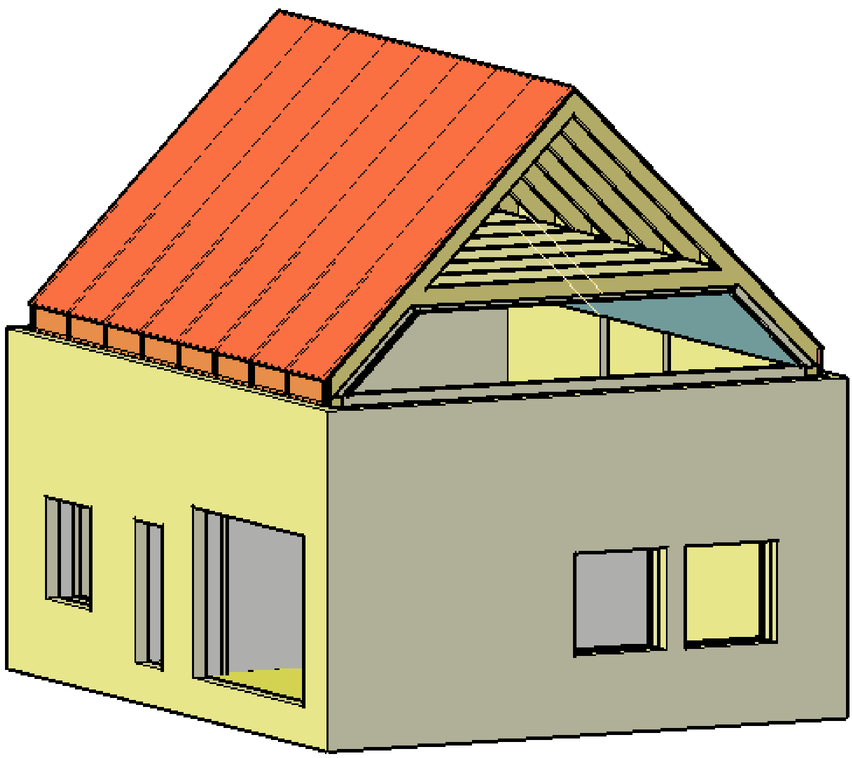

Fig. 3.30. Roof construction with insulation and gypsum boards

After the gypsum boards are attached to the construction of the roof, it is possible to finish the walls from the side. It can be done by extrusion of the existing solids below, and then slicing them according to roof slope direction. After all the external shell (mineral wool) should be joined into one object using UNION command. Complex shape of the building after this stage looks like below.

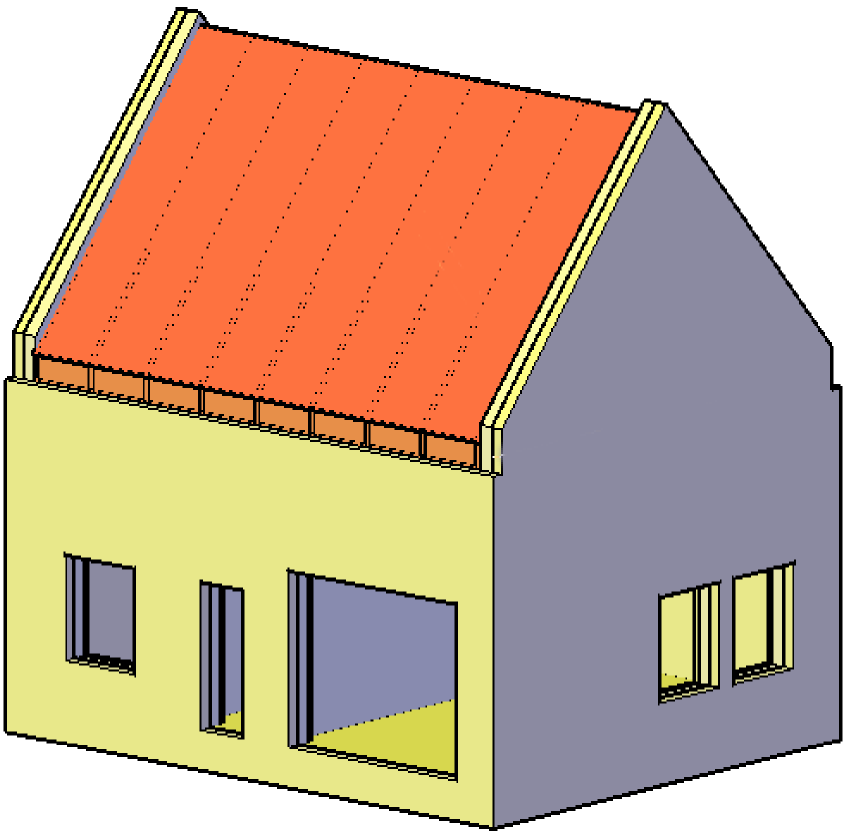

Fig. 3.31. View of modeled passive house with finished external barriers, roof and ceilings construction

3.9 *Attic walls*

To finish the construction details of the modeled passive house, one thing is still to be done – internal walls of the attic. To make working possible, it is suggested to turn off the roof layers, which will make the attic details visible. Then, two internal, load-bearing walls, made of aerated concrete ought to be extruded using *Solid Edit* feature. Length of extrusion could be default – after all they will be sliced to attach them to the gypsum boards position – for example 200cm should be enough in this exact case. To slice the extruded load-bearing walls according to the internal plane of gypsum boards it is suggested to turn on the *GypsumBoard* layer and change the *Visual Style* into the *3dWireframe* model, which will show all necessary edges to be cut. This is visible on Fig. 3.32.

Other necessary internal walls should be generated using box function according to attic projection at Fig. 3.2. Another thing is to prepare all necessary openings for the doors. This is presented on Fig. 3.33 and Fig. 3.34 and could be obtained using SUBTRACT command.

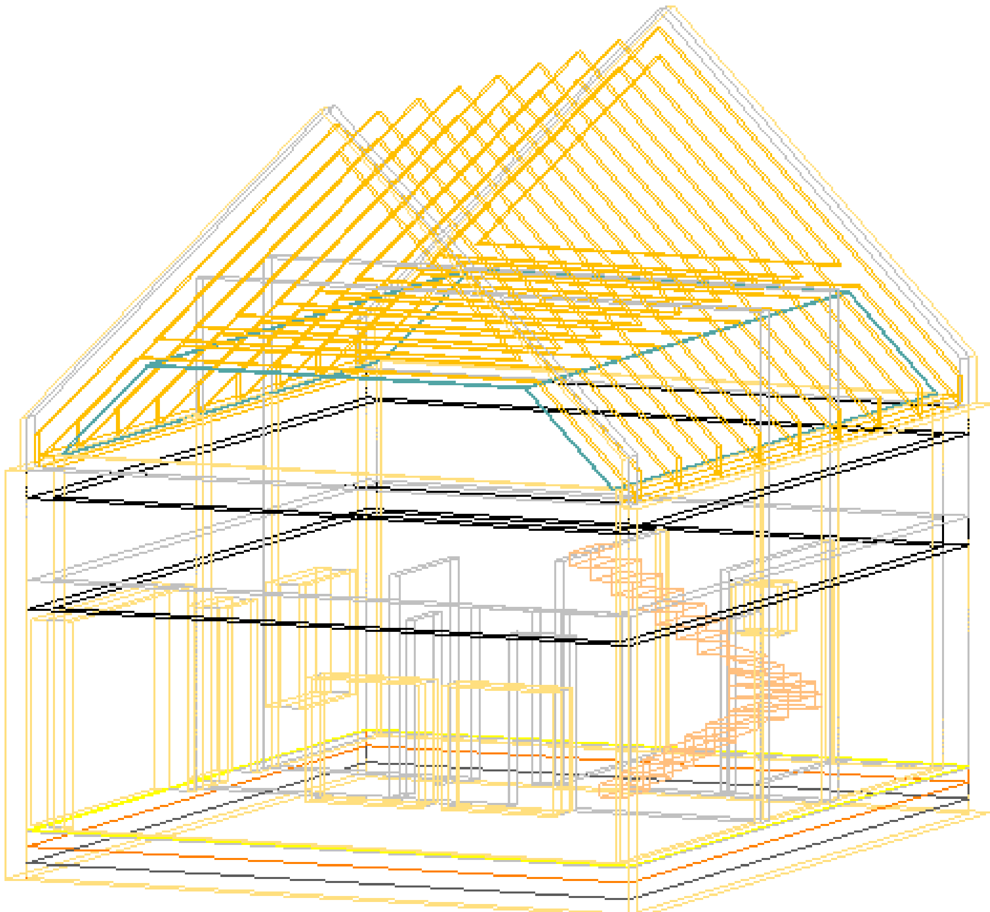

Fig. 3.32. View of modeled house in *3dWireframe Visual Style* required in some operations during attic modeling. Visible extruded load-bearing walls before slicing

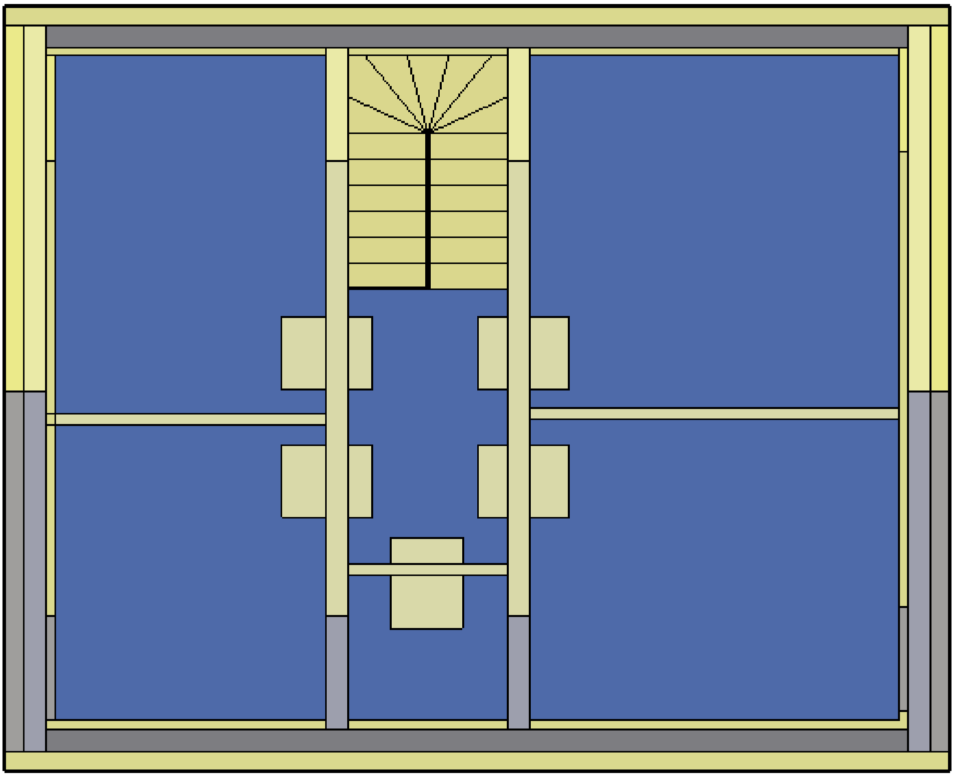

Fig. 3.33. Rooms distribution at the attic with blocks ready for subtraction

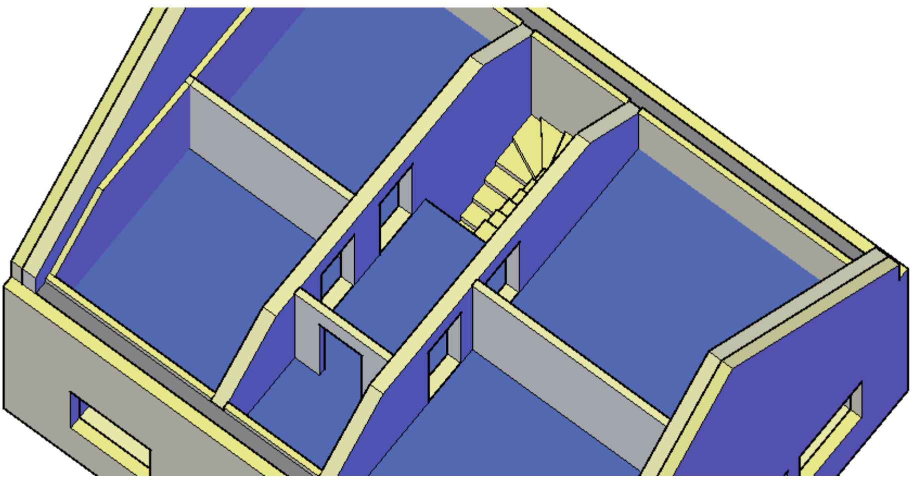

Fig. 3.34. Attic of the designed passive house

3.10 Details

At this stage, the passive house is almost ready from the point of view of the external envelope but also the most important indoor elements. To finalize this building it is required to arrange rooms of the ground floor and the attic with basic elements like windows, doors etc. It is assumed that no furniture or other elements will be presented in the modeled building and the special attention will be put on sanitary equipment typical for passive houses.

Important part of energy saving objects are windows (*Berge, 2001; Wolley et al., 2005; Wnuk, 2006*). To draw the window model, at least two layers should be created, for example *WindowFrame* and *WindowGlass*. Working on windows should be started from the profile modeling. Example, simplified model of window frame and the casement frame is presented at Fig. 3.35.

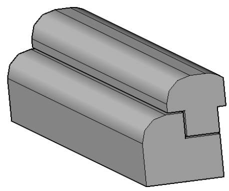

Fig. 3.35. Extruded profiles of window frame and the casement frame used to generate window models

After the profiles are extruded, they should be combined with other profiles to get the results presented at below figure. It is important to use the right slicing plane angle equal 45°, which will provide the correct connection between particular profiles.

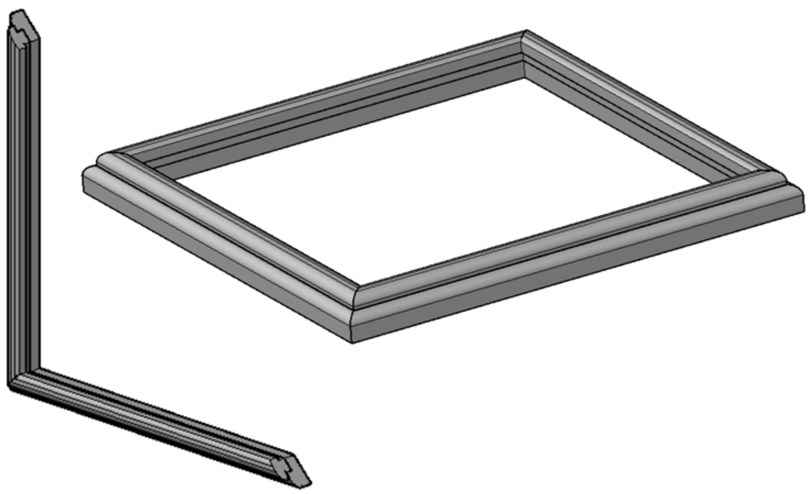

Fig. 3.36. Window frame and the casement frame during modeling

It is suggested to prepare in additional, external file the set of necessary windows and after they are ready, put them into the right places in the building model. Fig. 3.37 presents the modeled house with all mounted windows.

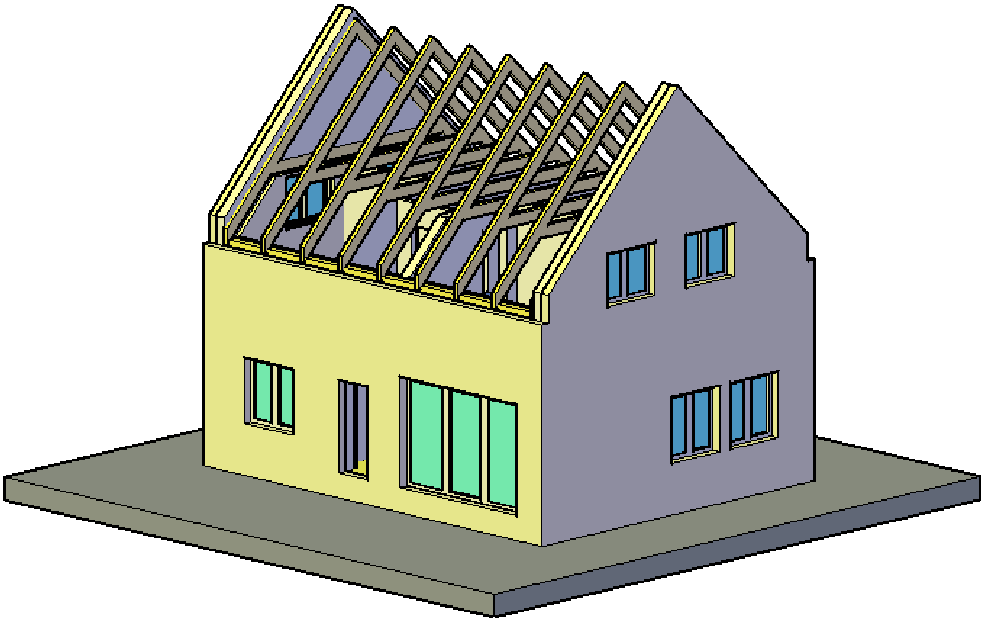

Fig. 3.37. Modeled building with ready windows

Other elements which could be presented in the modeled passive house are internal and external door, handles, banister in the stair case. It is strongly recommended to prepare those elements in independent files using typical 3D modeling functions like – drawing solid primitives etc. Figures below present the modeled passive house with basic details.

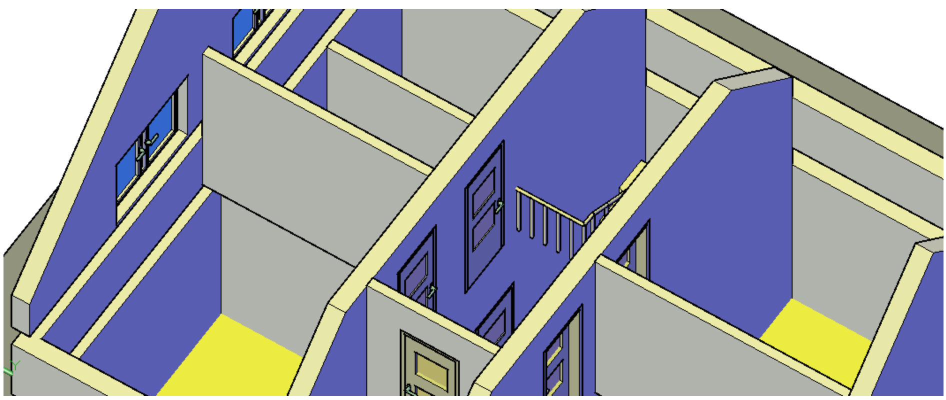

Fig. 3.38. Isometric view of the modeled house

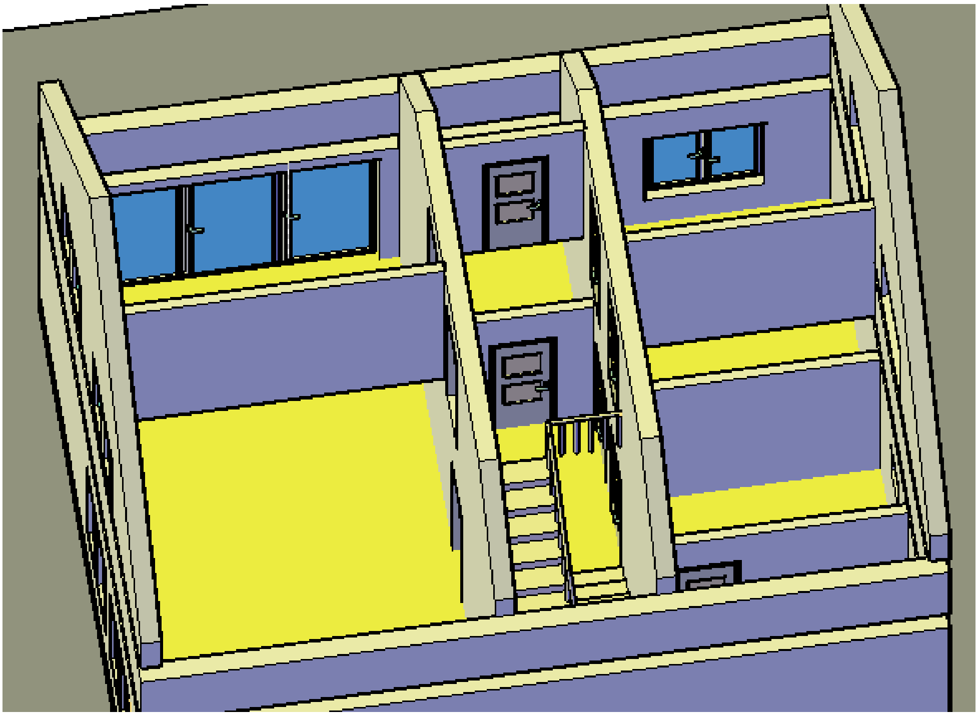

Fig. 3.39. Isometric view of modeled house

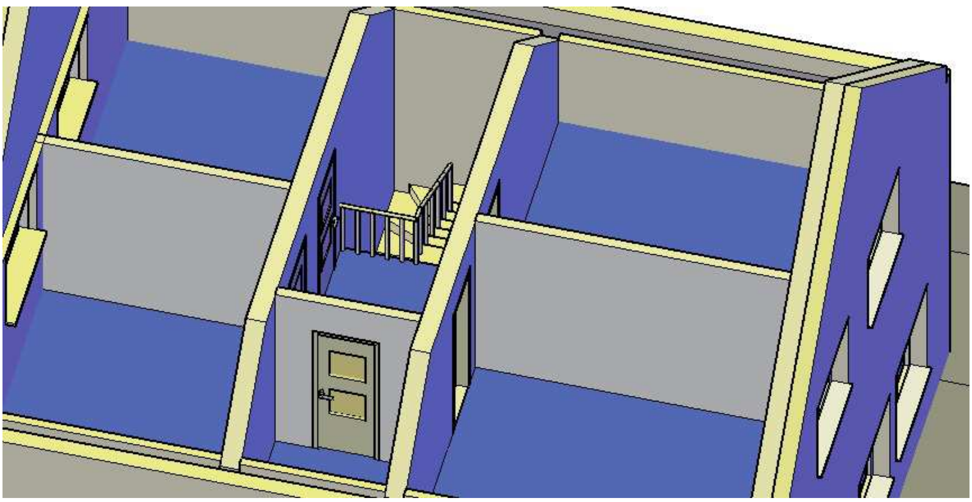

Fig. 3.40. Attic of the modeled house with details like door, handles, banister, internal and external window sills

3.11 Installations

The most important part of the following elaboration is sanitary equipment of the modeled house, especially that passive houses strongly differ from typical objects. It must be underlined, that suggested solution should not be treated as the design of the particular systems, thus no calculations will be presented. Anyhow the authors tried to keep the model close to the reality, that's why in some systems the pipelines, connectors or reducers have the realistic diameters or other dimensions. All sanitary fittings and other equipment do not support any of the equipment producers. All elements are simplified and generated by the book authors by themselves. Some devices may resemble the well-know producers devices, because they are typical in most energy-saving or passive buildings. Also it is assumed, that the range of sanitary elaboration is only limited to the internal part of the building, which means that external parts of the systems (sewage collector, ventilation ground exchanger etc.) will not be presented here.

Modeled passive house will be equipped with:

- ventilation system,
- water supply system,
- sewage system,
- solar system,
- heat pump system,
- rainwater system.

It is suggested here to use *Layer Property Manager* at this level of work and create new *Layers Filter* (Sanitary) which will separate sanitary elements from the building construction elements. This is presented at Fig. 1.14.

3.11.1 Ventilation system

It seems that ventilation system is the most important part of any passive house. This is mainly because it supports both fresh air and heating. According to (*Wnuk, 2006; Wnuk, 2007*) passive house is not equipped with the traditional heating system like typical houses are. It means that ventilation system removes hot, polluted, extract air from the particular rooms and delivers warm, fresh air into the another rooms (*Nantka, 2010*). This solution requires the following elements:

- inflow and outflow ducts removing and delivering air,
- ventilation unit with heat recovery (recuperator) and the radiator,
- ventilation ground heat exchanger supporting warmed, fresh air to ventilation unit,
- air inlet with filter and the exhaust.

It must be underlined that two final elements of the list above are out of range of this elaboration, that's why ground heat exchanger, inlet and exhaust will not be modeled here. Another assumption is that ventilation ducts will be presented here without suitable insulation layer. It must be underlined, that all ducts presented here should be supported with mineral wool cover, which would prevent heat loses during air delivery. Anyhow it would hide the ducts distribution and the details of ducts connections, that's why the authors of this elaboration had decided to avoid this part of the system.

For the elaboration, calculations of ventilation ducts diameters and other ventilation system are avoided, anyhow detailed information about these systems is presented in the following books (*Godish, 2001; Martin and Oughton, 2002; Chadderon, 2004; Jones 2005, Maier and Tejchman, 2006; Albers et al., 2007; McDowall, 2007; Raczkowski et al., 2010; Pełech, 2011*).

For the modeled ventilation system the galvanized steel ducts were used with the following diameters: 150mm, 100mm and 80mm (Fig. 3.41). Among them, there are also bends, reducers and other elements presented below.

It is strongly recommended to prepare the elements of the ventilation system in a separate file and after they are ready paste them into the main project file. This would make working with details easier and will be better for the computer performance.

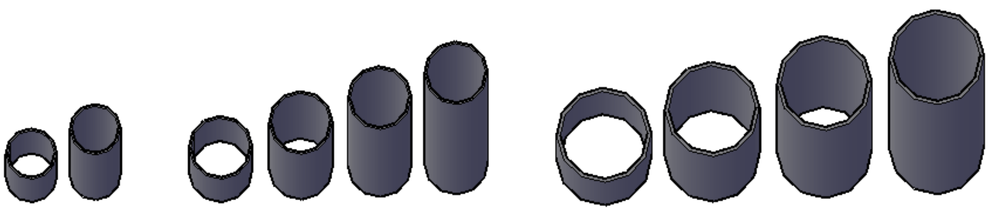

Fig. 3.41. Ventilation ducts prepared in external file

Bends (Fig. 3.43) and other elements can be done using EXTRUDE function according to the previously generated PATH, which is presented at Fig. 3.42.

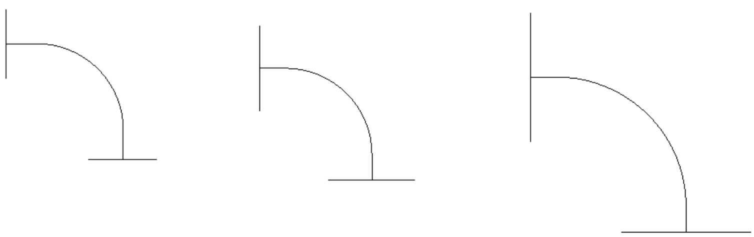

Fig. 3.42. Profiles prepared to generate bends for ventilation ducts

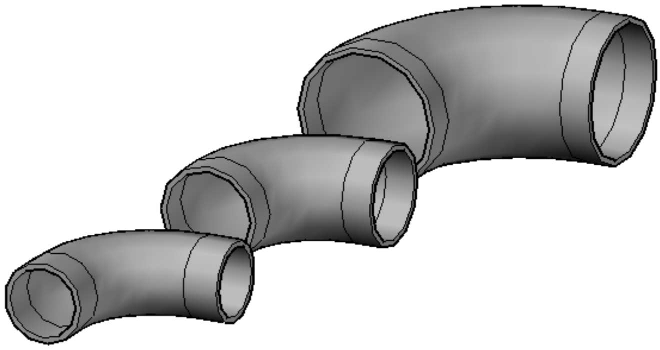

Fig. 3.43. Ventilation bends

Another elements which are necessary for the ventilation system of the modeled house are ventilation unit (recuperator) and ventilators (air inlets and extractors). After those are ready they should be pasted to the modeled house. Modeling of the system relies on pasting of the pre-arranged elements and putting them into the correct position to form the expected system of the ducts. It is assumed that at first floor the ducts will be inserted in the suspended ceiling space, and at the attic above the cellar beams and the attic ceiling. Fresh air is delivered to the living rooms and removed from kitchen and bathrooms.

To generate this system, the following layers were formed:

- *VentRecuperator*,
- *VentDuctInflow*,
- *VentDuctOutflow*,
- *Ventilator*.

Fig. 3.44 presents the projection of the ground floor and the ventilation system. There are visible ventilation ducts running in the space of suspended ceiling. To prevent any collisions of the ducts, the crossings are guided in the boiler room where is enough space for them (no suspended ceiling).

Attic ventilation ducts (Fig. 3.45) are conducted over the ceiling made of gypsum board and the insulation between the collar beams. Vertical ducts are conducted in the both bathrooms and are to be covered with gypsum board walls.

Figures presented on the next pages show ventilation system of the described passive house. Besides the ducts, there are visible recuperator and the ventilators. Fig. 3.46 is an isometric view of the whole system. Inflow and outflow ducts are generated in different layers, that's why they differ in color. Fig. 3.48 presents the details of ducts distribution above the attic ceiling with visible bends, pipe tees, reductions. Finally, Fig. 3.47 and Fig. 3.47 present the views of the modeled ventilation system with particular ceilings.

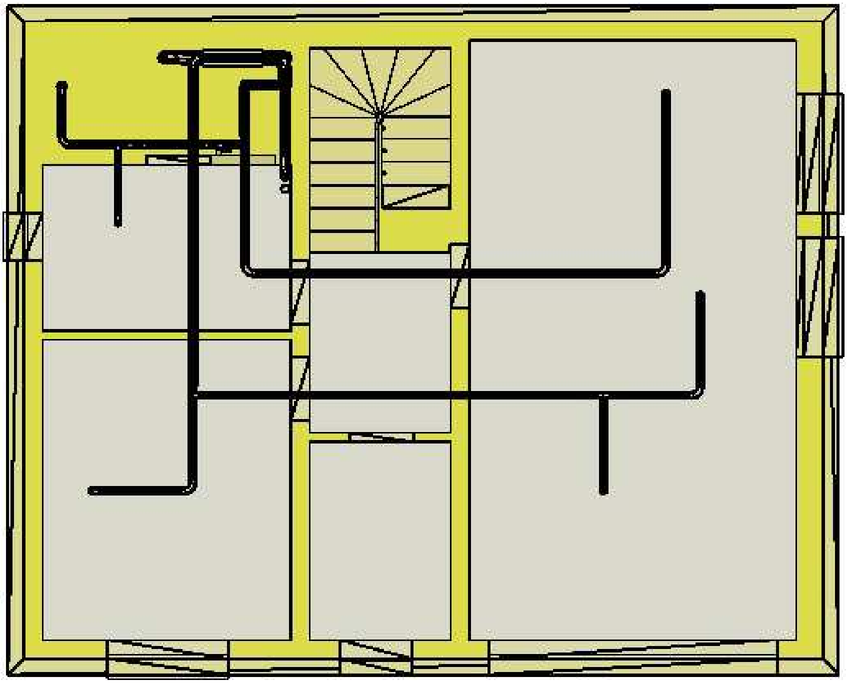

Fig. 3.44. Projection of ground floor with ventilation system

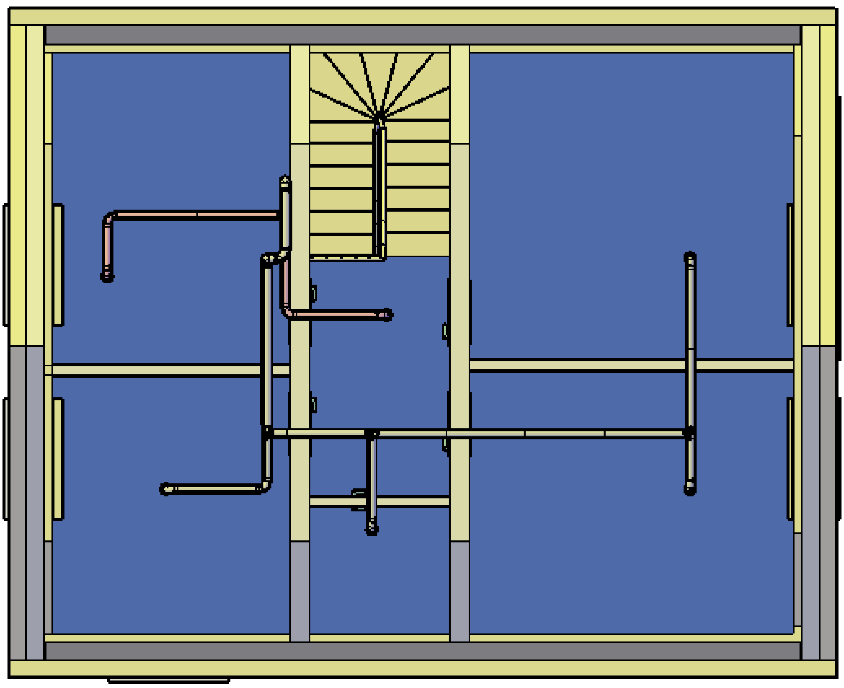

Fig. 3.45. Projection of the attic with ventilation ducts

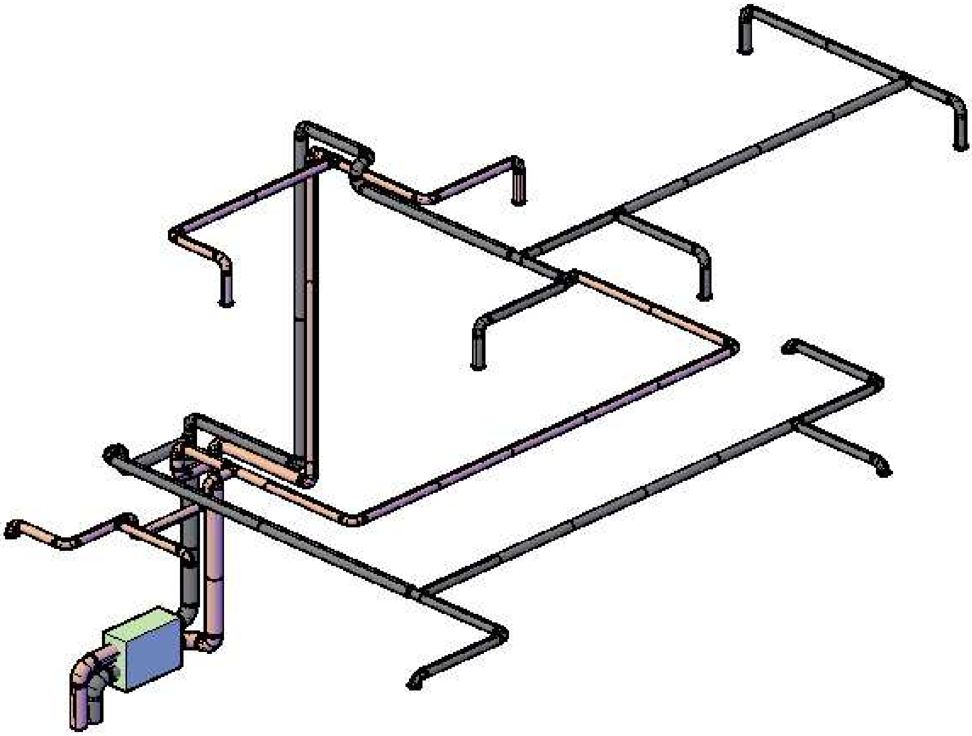

Fig. 3.46. Isometric view of ventilation system

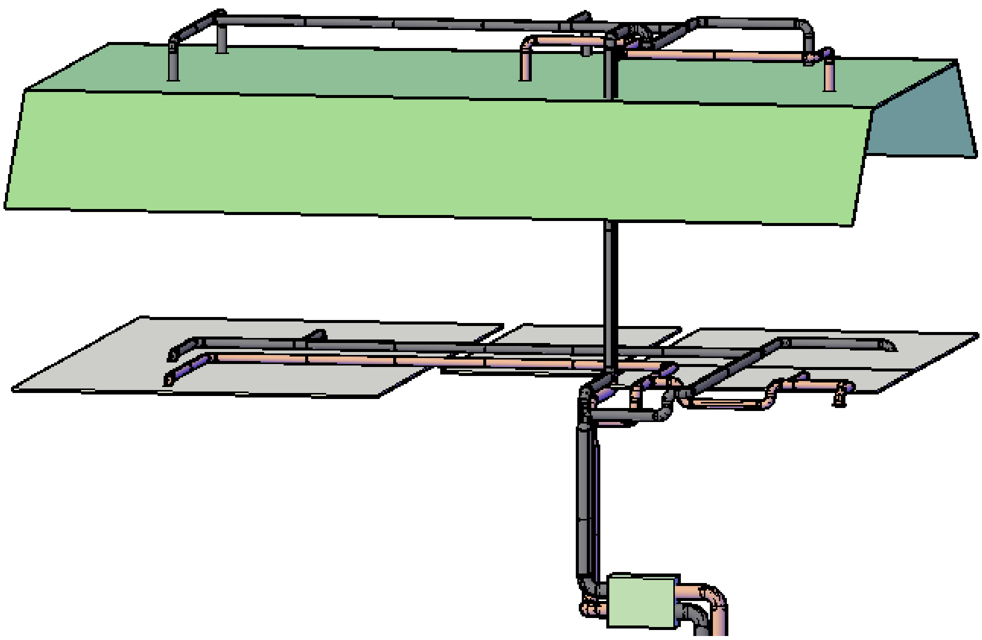

Fig. 3.47. Ventilation system and ceilings

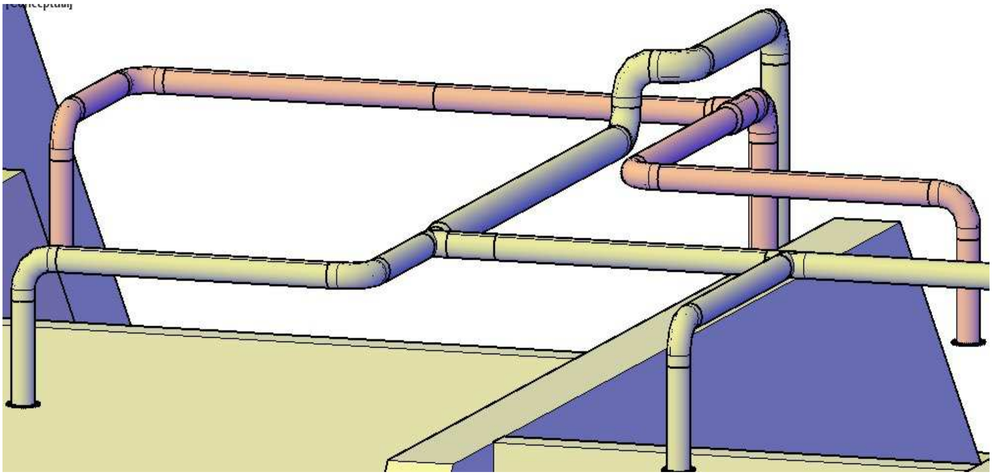

Fig. 3.48. Details of ventilation system ducts above the attic

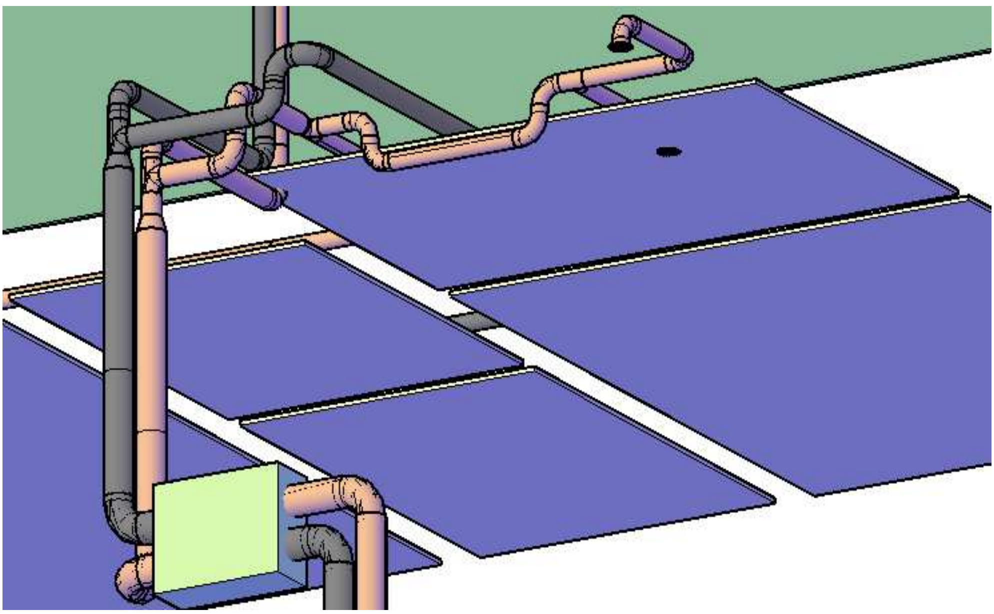

Fig. 3.49. Part of system with suspended ceiling

3.11.2 Water supply system

Water supply system of the modeled house consists of three parts: cold water pipelines, hot water pipelines and hot water circulation system, circulating water to the distant take off points. Detailed description of water supply systems is presented in the following books and standards (*PN-92/B-01706; Brydak-Jeżowiecka et al., 1994; Sosnowski et al., 2000; Chudzicki, 2006; Gassner, 2008; Muszyński, 2009; Chudzicki and Sosnowski, 2011; Orłowska-Szostak, 2011; Orłowska-Szostak and Orłowski, 2011; Panas, 2011; Chudzicki, 2012*). Contrary to the previously described ventilation system, it is assumed that water system pipelines will be covered in thermal insulation layer which will differ in color. It is mainly caused by the fact that water pipes are of small diameters and would not be clearly visible in the modeled object. Also, it must underlined that insulation is required by many regulations for this systems, for example Regulation of the Polish Minister of Infrastructure dated 12 April 2002 on technical requirements which have to be met by buildings and their situation (Journal of Laws – Dz. U. Nr 75, item 690 with subsequent amendments). For that aim the developed model was simplified to common diameter of pipelines equal 32mm which would cover the water pipeline dimension together with the insulation layer. Another assumption is that no take off points will be presented in this model and the authors will mainly focus on development of the water supply system, without sanitary equipment, which may be dependent on each user. That's why the following elements will not be presented: taps, mixers, shower heads, sinks, washbasins, lavatory pans etc.

Also, comparably to the previous presented system, it is recommended to prepare the necessary fittings in a separate file which will make modeling more convenient. To generate necessary elements it is a good idea to use data details of fittings producers. Below figures present the example fitting elements prepared for the described model. Among them there are contained ball valves, water meter, backflow preventer, non-return valve, filter, relief valve and air bleeder. Also, it is important that such prepared fitting will be applied in development of other systems of the modeled passive house.

Other elements like expansion vessels, pumps, hot water tank are not presented in this part of sub-chapter, anyhow they will be mentioned during modeling of the described system.

As it is suggested in (*Wnuk, 2006*), water supply pipeline enters the building settled on reinforced concrete from below, that's why it comes vertically to the boiler room and then runs along the water meter console to the whole system (Fig. 3.53)

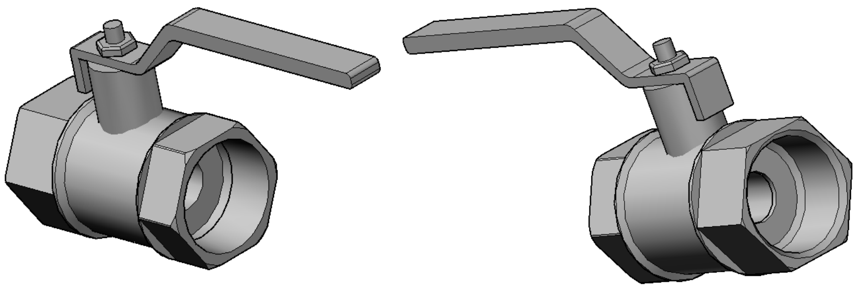

Fig. 3.50. Ball valves prepared for water supply system

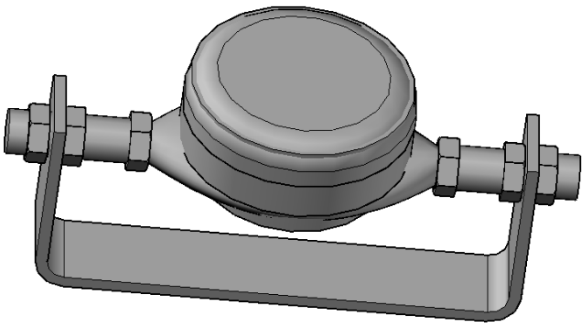

Fig. 3.51. Model of water-meter console

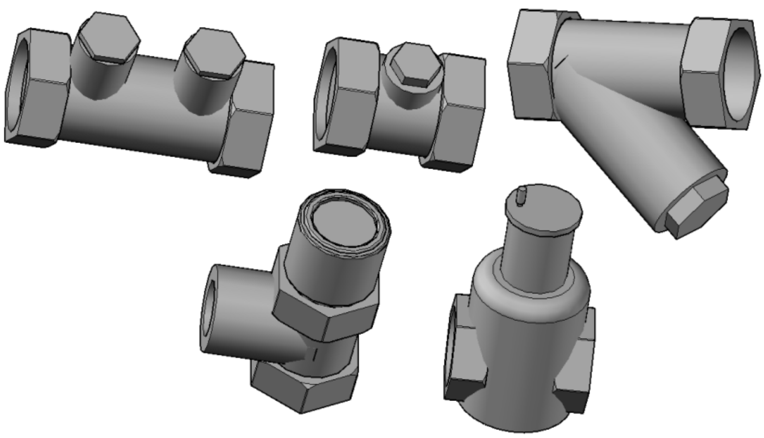

Fig. 3.52. Fittings prepared for the modeled installation: backflow preventer, non-return valve, filter, relief valve, air bleeder

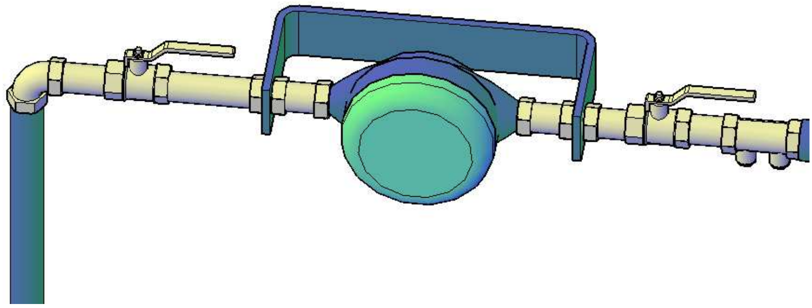

Fig. 3.53. Water supply entry in the modeled object (visible ball valves, water-meter console and anti-contamination valve)

After the water meter console, cold water pipeline spreads into the whole system and into hot water container. Fig. 3.54 presents cold water entrance and hot water container with some of the fittings.

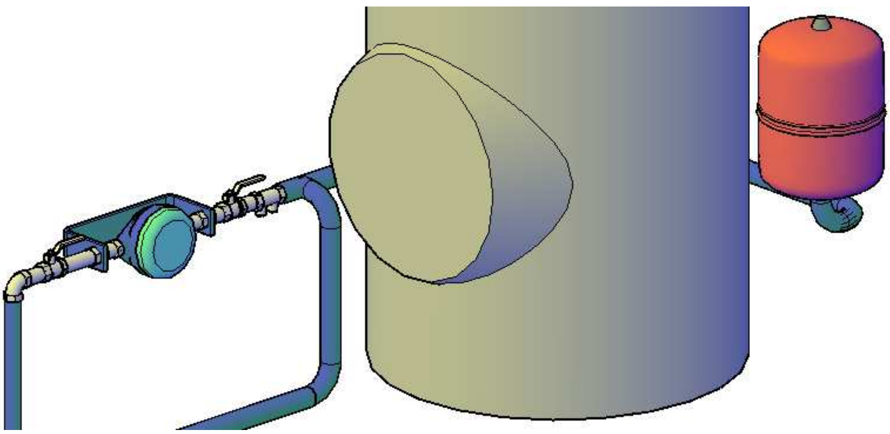

Fig. 3.54. Cold water entrance and hot water container with expansion vessel visible on the right

Fig. 3.55 presents hot water container with all necessary fittings: non-return valve, relief valve, expansion vessel. There are also visible hot water and hot water circulation systems, together with circulation pump and the necessary equipment.

Pipelines of the described system are conducted in the cement floor and partially in internal insulation of the building. To generate the pipelines it is suggested to prepare circles of the assumed pipes dimension, which will serve as pipes profile for extrusion. Then the guiding paths (Fig. 3.56) should be prepared and EXTRUDE function used with PATH sub-option (Fig. 3.56). Continuation of the pipelines extrusion can be executed using SOLIDEDIT sub-function – *Extrude Faces*. It is strongly recommended to be aware of possible collisions with particular pipelines but also with the ventilation ducts or building construction elements.

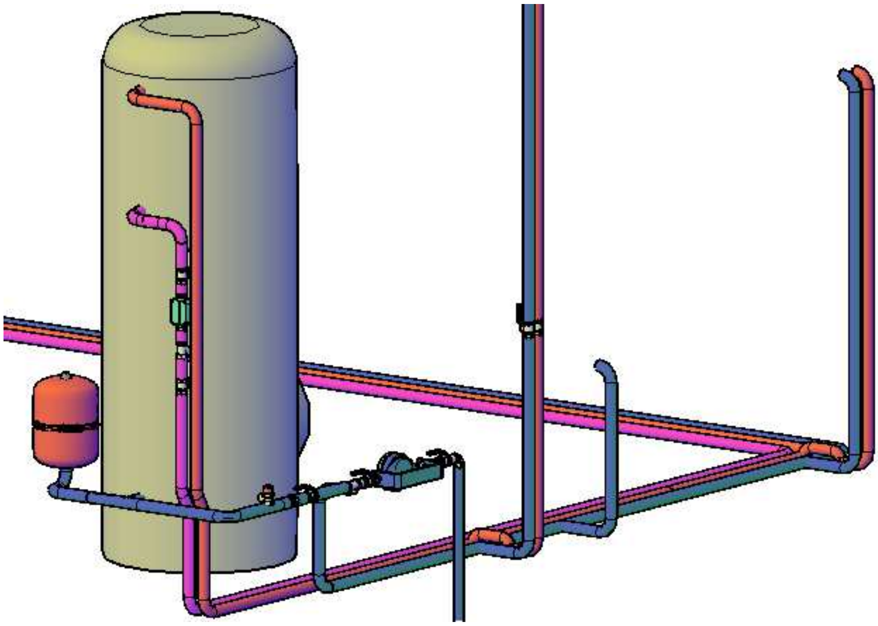

Fig. 3.55. Part of the modeled water supply system

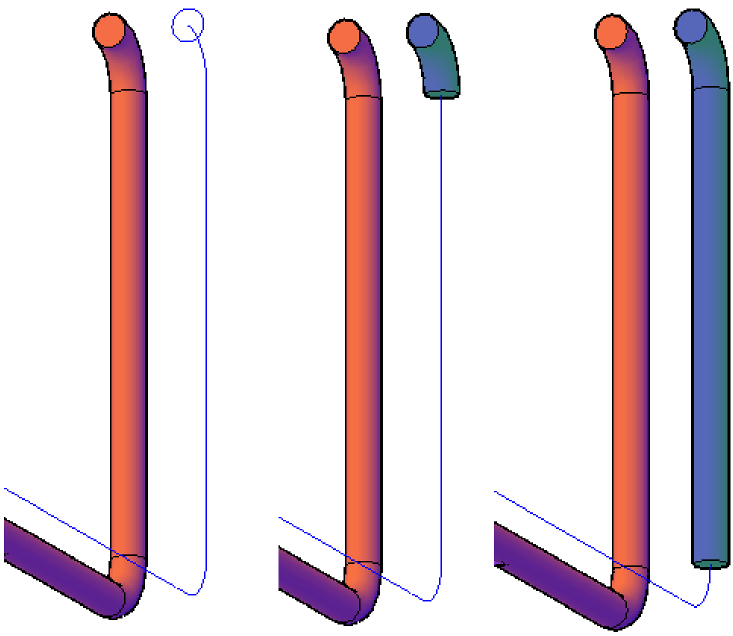

Fig. 3.56. Water supply system pipelines modeling. First stage requires pipe profile preparation together with extrusion paths, second step is extrusion of the profile and continuation using SOLIDEDIT command

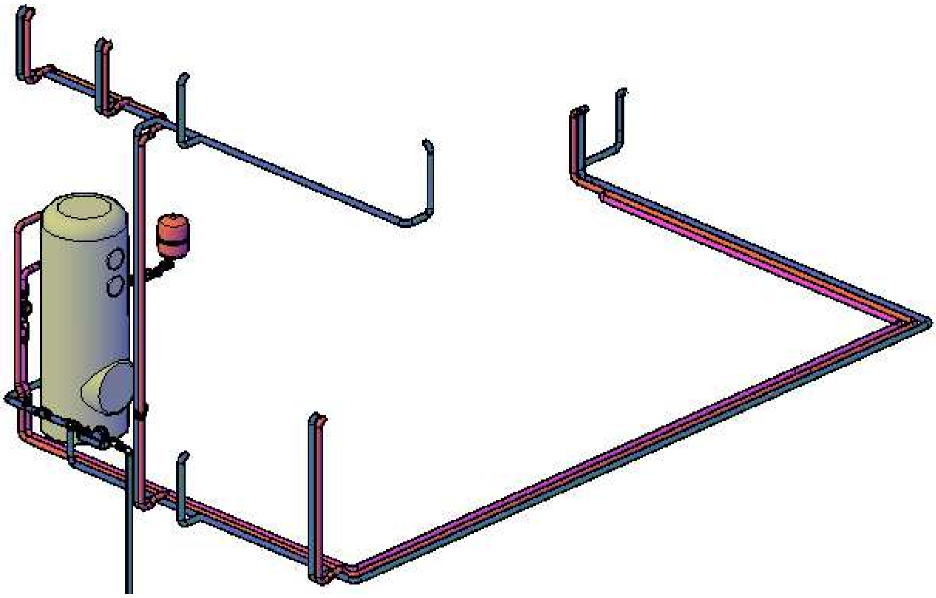

Fig. 3.57. Water supply system of the modeled building

3.11.3 Sewage system

It is obvious, that domestic sewage is disposed with sewage system. This system is very similar to other systems in traditional houses. The most visible difference from normal buildings is the conduction of the main sewage pipe, which can be placed inside the reinforced plate, between the reinforcement (*Wnuk, 2006*). Another difference is the application of sewer vent valves instead of sewer vent pipes. This is solution is applied to prevent the roof cover from being interrupted. In detail sewage systems are discussed in the following standards and books (*EN12056-2:2000; PN-EN12056-2:2002; Chudzicki and Sosnowski, 2009; Gassner, 2008*).

As it was presented before, in previously described systems, the most efficient way of working is to prepare the necessary pipes models and other elements in a separate file and then paste them into the main model. The following figures present the prearranged models of sewage system elements.

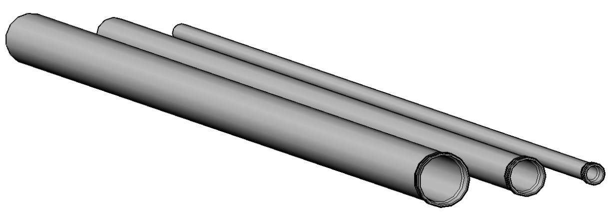

Fig. 3.58. Sewage PVC pipes with the following dimensions 160, 110 and 80mm, finished with socket and the spigot on the opposite sides

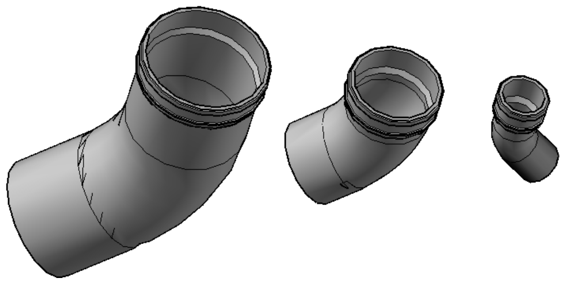

Fig. 3.59. Sewage bends 45° with different diameters

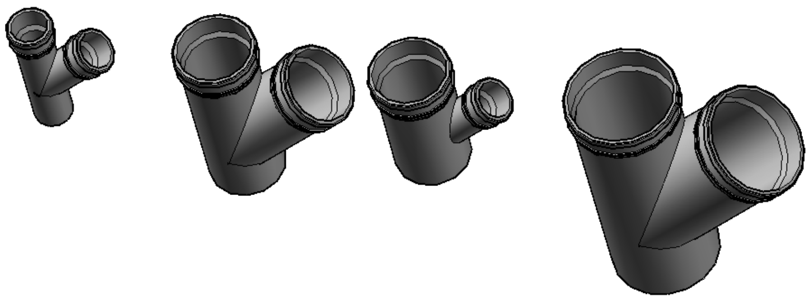

Fig. 3.60. Y-branches (45°) of sewage pipelines with different diameters and types

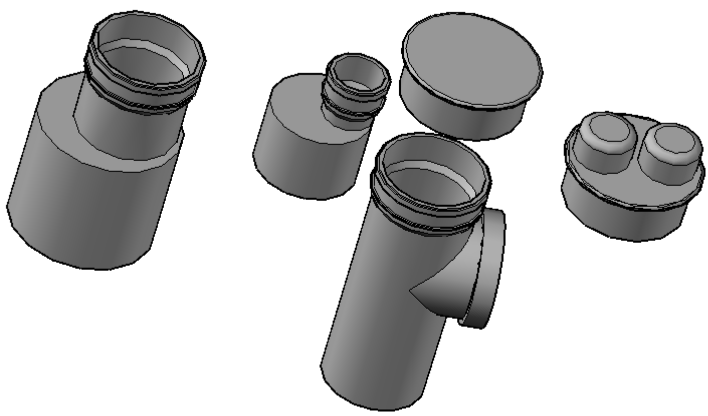

Fig. 3.61. Other elements of sewage system: reducers, vent valve, inspection eye etc.

Modeling of the sewage system is time consuming because it requires to prepare a lot of elements and after those elements are ready, they should be placed in suitable position and combination, to obtain the satisfactory results. It often requires to change the *User Coordinate System* (UCS) and rotation of the objects using 3DROTATE function. Figures presented below show the details of modeled sewage system details.

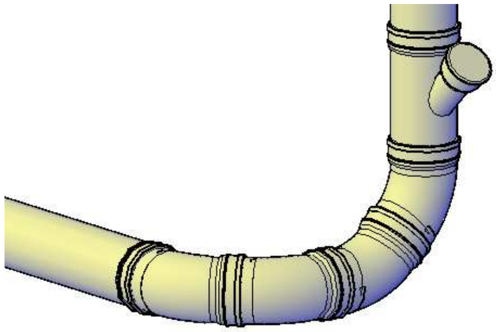

Fig. 3.62. Example of the sewage stack with bends and y-branch for sink drain

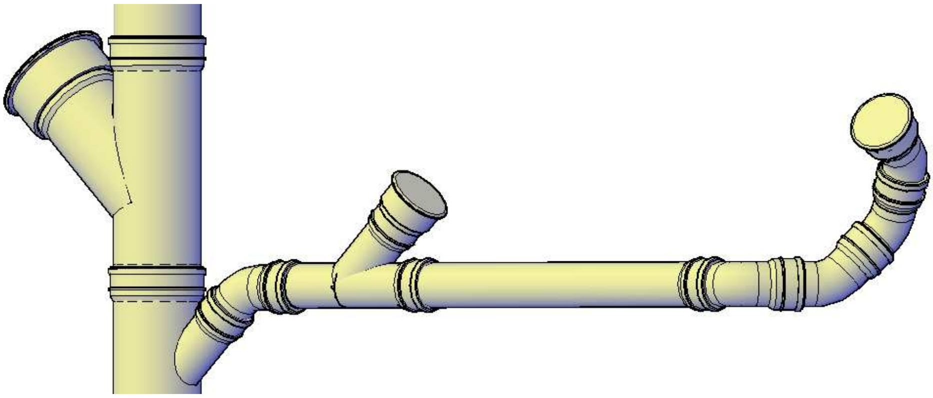

Fig. 3.63. Example of the sewage stack with bends and y-branch for sink drain

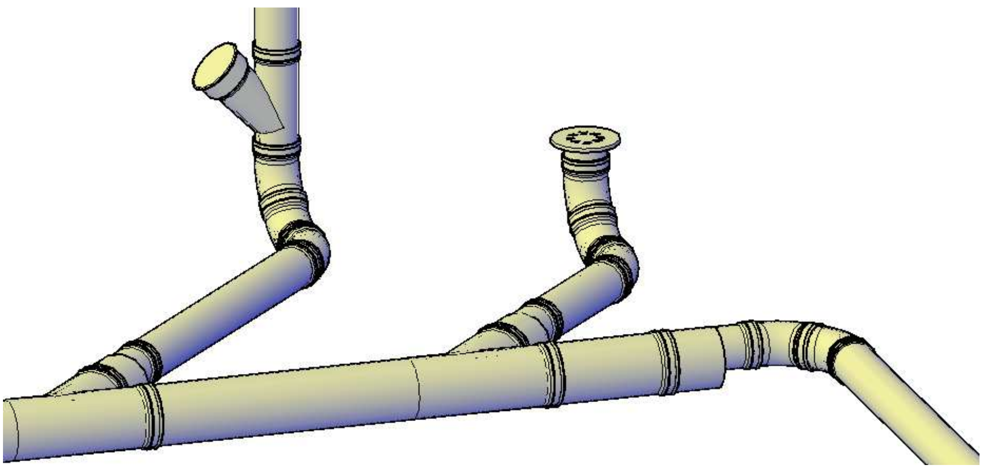

Fig. 3.64. Building main sewer with visible reduction, floor drain and the sewage stack

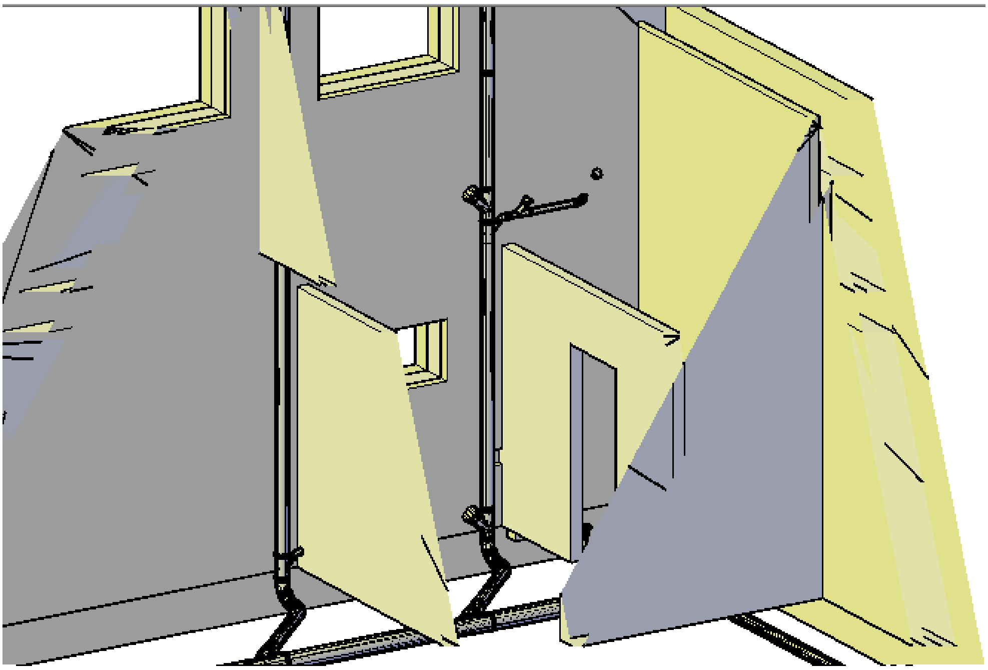

Fig. 3.65. Isometric view of sewage system in the modeled house presented using 3DCLIP command

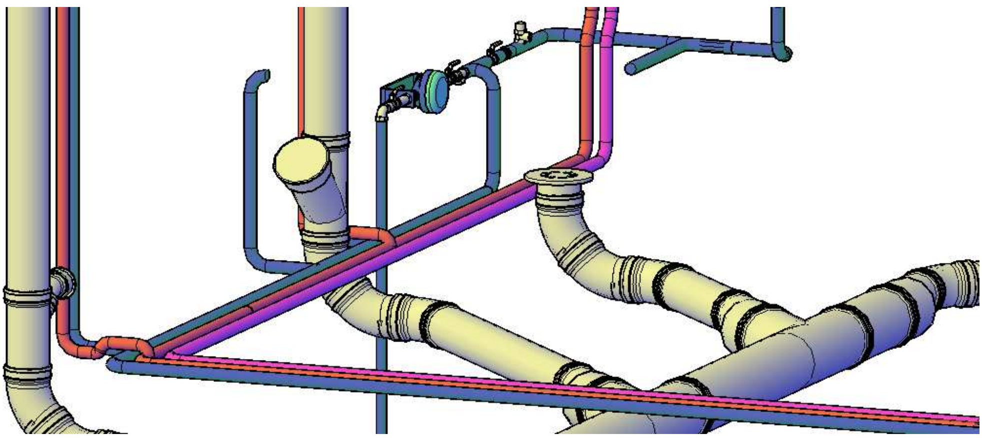

Fig. 3.66. Combination of sewage and water supply systems with visible bypasses to avoid collisions of the pipelines

3.11.4 Solar heating system

Solar system of the described passive house is applied for hot water production and consists of the following elements:

- solar collectors,
- solar pump station (with pump and pressure meters),
- water tank,
- necessary valves and other fittings.

Detailed information about solar heating systems can be found in (*Galloway, 2004; Hall and Greeno, 2005; Foit, 2005; Danielewicz and Szulgowska-Zgrzywa, 2005; Albers, 2007; Wnuk, 2007; Wiśniewski et al., 2008*). It is assumed that pipes applied for the solar installation are made of copper with synthetic rubber insulation and the common diameter is equal 50mm. Modeling of pipelines is analogue to the processes described on sub-chapter 3.11.2 and is presented at Fig. 3.56.

As it was described before, it is a good habit to prepare all necessary elements in a separate file and then apply them in the main model. Fig. 3.67 presents the solar panels ready to be put on the roof of the modeled house.

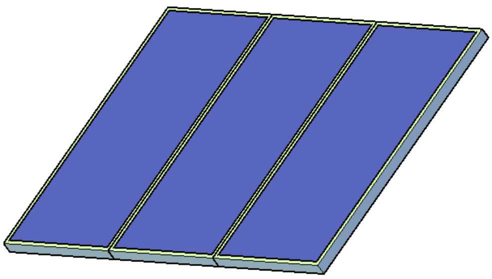

Fig. 3.67. Solar panels consisting of solar frames and the absorbers

Below figures present the whole solar installation.

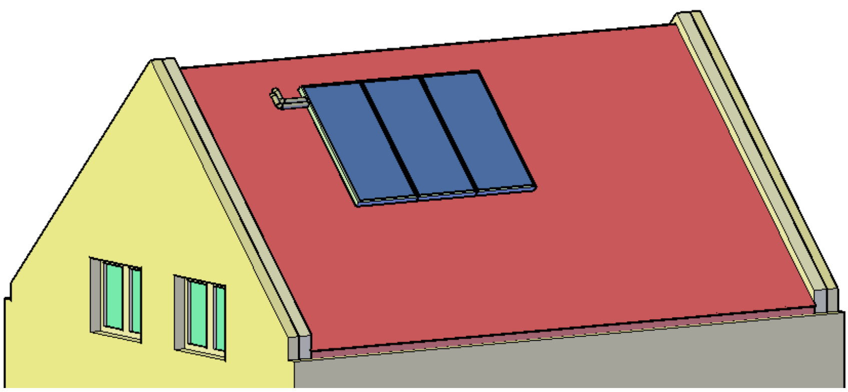

Fig. 3.68. Solar panels on the roof of the modeled passive house

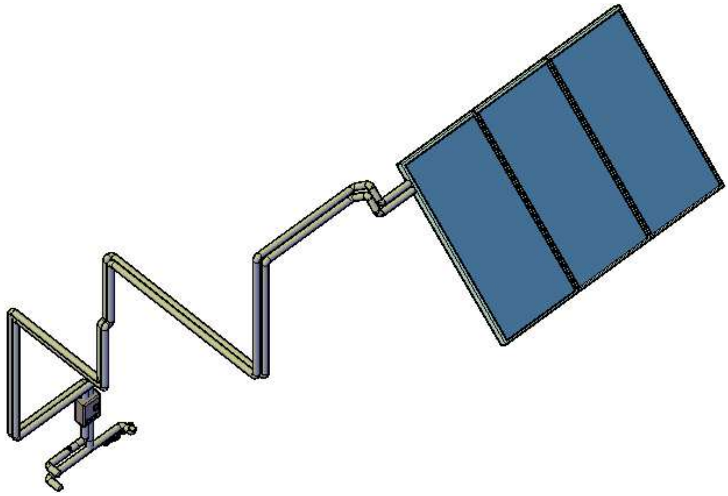

Fig. 3.69. Isometric view of the whole solar installation (visible solar panels, pipelines and solar pump station)

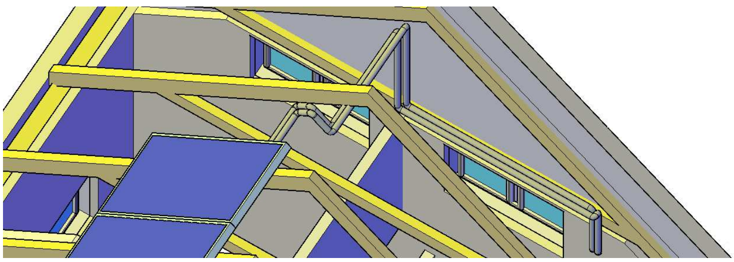

Fig. 3.70. Solar panels on roof construction and pipes conduction at the rafters space

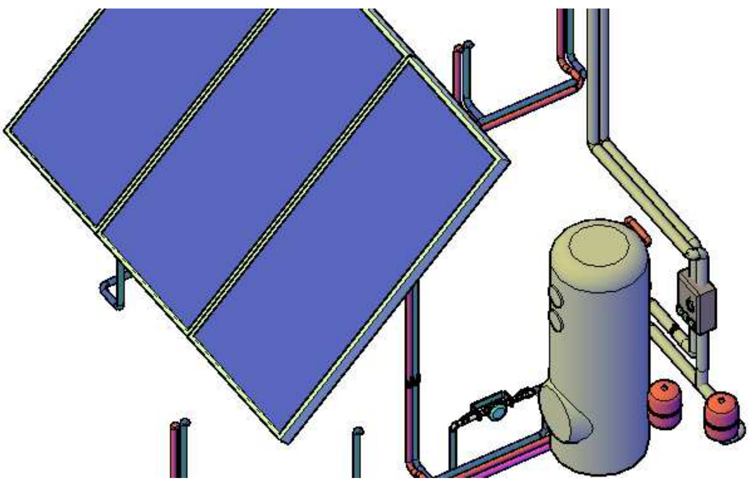

Fig. 3.71. Combination of solar installation with water supply system

3.11.5 Heat pump system

According to (*Wnuk*, *2006*) heat pump is a suitable heat source for energy-saving and passive houses. Working of heat pump relies on conversion of low temperature energy (soil, soil water, air) into the high temperature energy and can be compared to the traditional fridge. The most popular are compression heat pumps, driven by electric compressors. Other idea of heat pumps are absorption heat pumps which are fueled by natural gas or LPG (Liquid Petroleum Gas) and are currently less popular from the previously mentioned.

In this book, there will be presented the typical solution applied in modern systems – compression heat pump, providing heat for heating (radiator in ventilation unit) and for hot water production (water tank).

As it was described in the previous systems, it is strongly recommended to use external files to prepare necessary devices and fittings. For this system it was possible to use previously prepared valves and other fittings. The only required element was the heat pump which was generated basing on the idea of one of popular producers (Fig. 3.72).

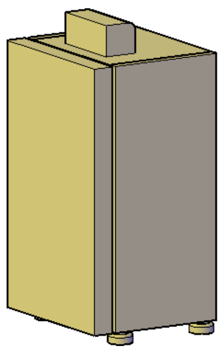

Fig. 3.72. Heat pump model

In the described model it is assumed that two pipes (left and right) are going to the ground, the lower source of energy, which is not further presented in this elaboration. Another two pipes provide heating cycle, delivering heat to hot water tank and ventilation unit radiator. Another assumption is that pipelines are also insulated and can be modeled using the same diameter as solar installation pipes. The way of modeling of pipelines is completely comparable to previously described water supply system pipes (Fig. 3.56) using EXTRUE and SOLIDEDIT functions and will be no more precisely presented in this sub-chapter. Fig. 3.73 presents two visualizations of the modeled heat pump armed with the necessary fittings (expansion vessels, valves, circulation pumps etc.). Fig. 3.74 and Fig. 3.75 present the whole heat pump system, providing heating factor to the ventilation unit radiator and hot water tank.

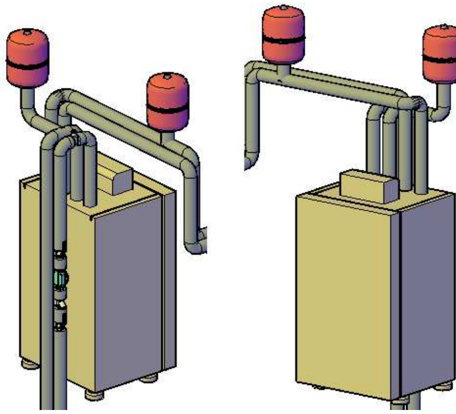

Fig. 3.73. Isometric views of modeled heat pump (left – back, right – front)

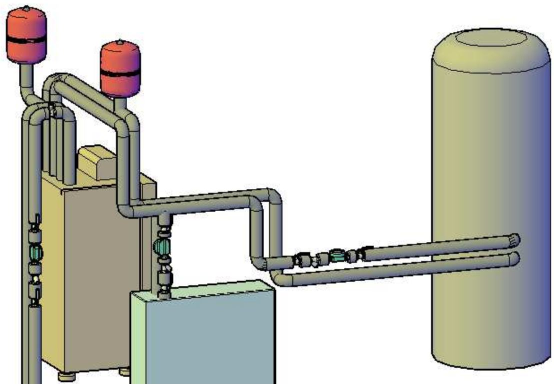

Fig. 3.74. Visualization of heat pump system of the modeled passive house

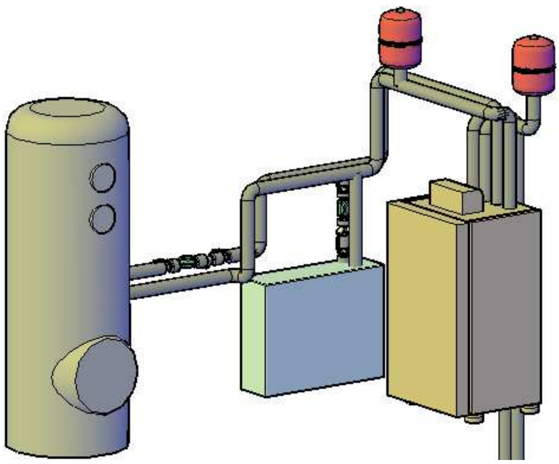

Fig. 3.75. Visualization of heat pump system of the modeled passive house

3.11.6 Rainwater system

Rainwater system of a passive house does not differ from typical solutions. Some differences may be caused by building architecture etc. but they are not important from the point of view of this elaboration. Also it should be underlined here that ecological solutions for modern houses may consider utilization of rainwater for potential application like water storage for garden watering or rainwater reuse for lavatory pan washing etc. which is widely discussed in (*Tang et al., 2007; Mucha and Jodłowski, 2009; Królikowska and Królikowski, 2012*). Anyhow, these solutions exceed the range of this elaboration and the described model will only present the major pipes draining the modeled house.

The dimension of rainwater pipes is assumed to be 125mm. For the roof drainage there are used two surface channels and two rainwater stacks, delivering rainwater below the ground surface and then to the rainwater network or draining system. Pipes and channels were prepared in external file and pasted to the main model. Fig. 3.76 presents the surface channel (rainspout), which was modeled using the extrusion of the closed polylinear profile with sides. Fig. 3.77 and Fig. 3.78 present the surface channel with rainwater stack and visible offset pipe.

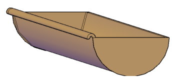

Fig. 3.76. Modeled rainspout

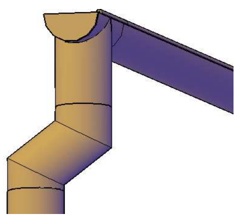

Fig. 3.77. Rainspout with offset pipe

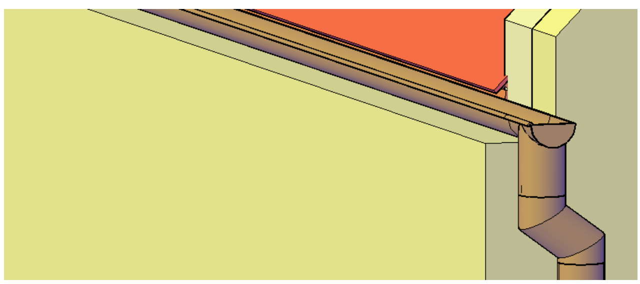

Fig. 3.78. Roof drainage of modeled passive house with details of rainspout and stack

3.11.7 Review of all systems

This subchapter presents the comprehensive view on the whole building systems. It contains the screenshots of all systems, showing dependences between them and coordination of the particular systems to avoid collisions and pipelines intersections. Fig. 3.79 and Fig. 3.80 show only sanitary systems without the construction details of modeled house.

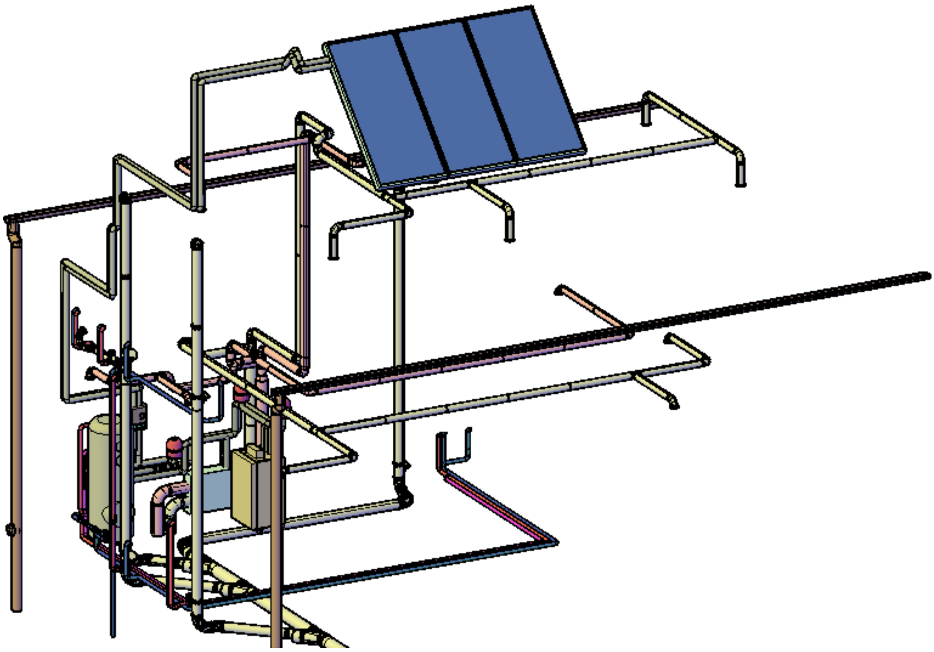

Fig. 3.79. All sanitary systems modeled in the described passive house

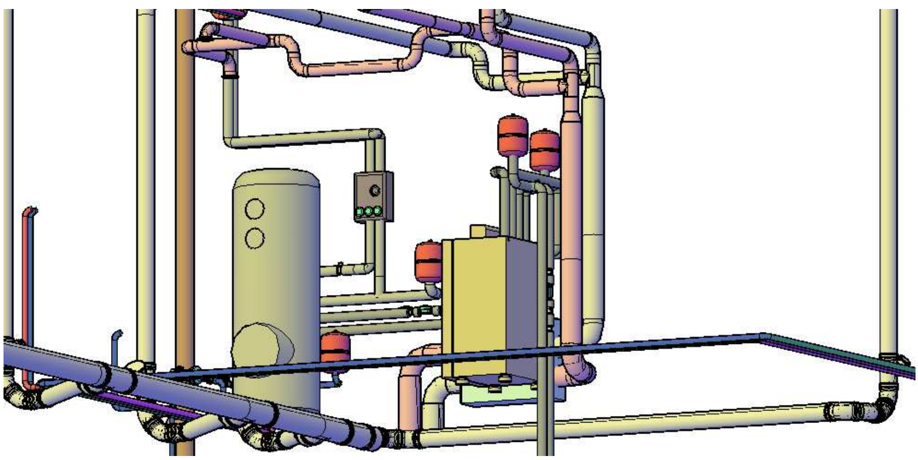

Fig. 3.80. Sanitary systems visible in boilers room

All figures below demonstrate the three-dimensional clips of the sanitary systems of the modeled passive house with special attention put onto the boiler room.

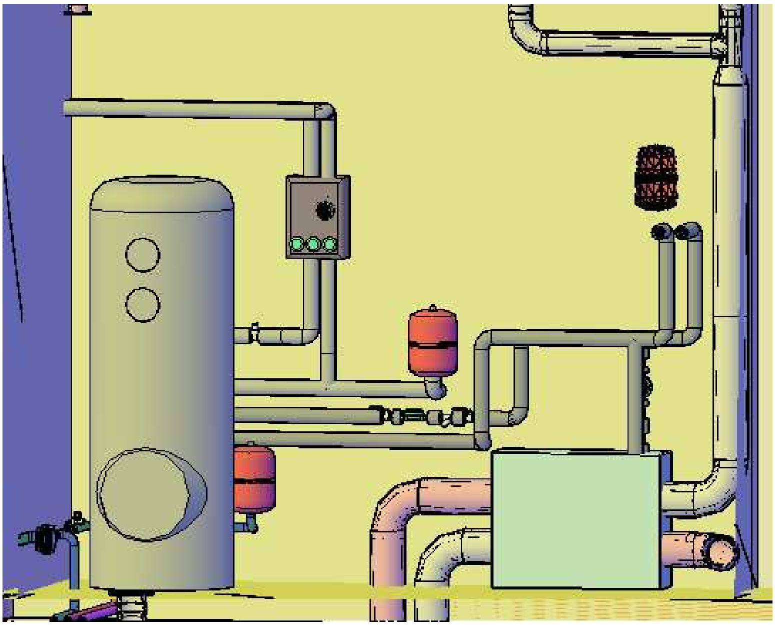

Fig. 3.81. Cross-section of boiler room (view from the front of the room)

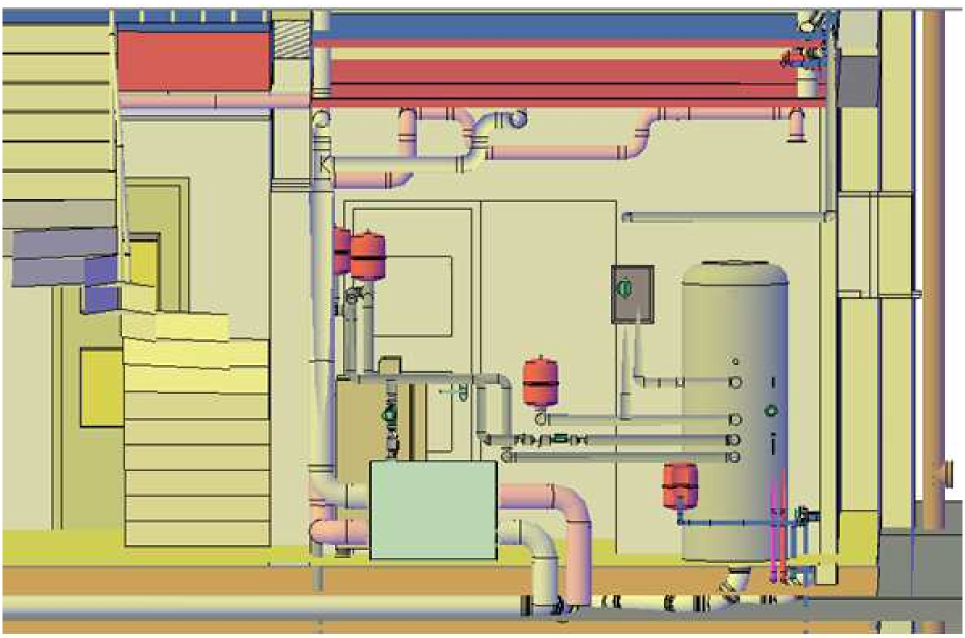

Fig. 3.82. Cross-section of boiler room (view from the back)

3.11.8 Rendering of the modeled passive house

Theory for rendering procedure was widely presented in the first part of this elaboration, 1.12 sub-chapter. It must be significantly underlined here, that rendering is an advanced process, with large requirements for computer resources. The quality of the obtained results mainly depends on the vector 3D model quality, but also suitable selection of applied materials, setting the suitable lightning and shadows. The aim of this sub-chapter is to show the potential of rendering feature as a useful tool for visualization of engineering objects. Due to monograph limitations not all possible details will be presented in this book, anyhow a lot of information about professional features of rendering is presented in the following elaborations (*Omura, 2009; McFarnland, 2009; Finkelstein, 2011*) and technical documentation of AutoCAD 2012 available at: *http://usa.autodesk.com.*

To obtain the interesting render scenes of modeled 3D objects, the most important and spectacular part is assigning the materials to the particular objects. This is always easier if the modeled "vector" was prepared using in proper order, with suitable layers organization. The example of this can be modeling of the window, where at least two or more layers are necessary – *WindowFrame*, *WindowGlass*, but also *WindowsillExternal*, *WindowsillInternal*, *Handle*. With suitably generated files it is always easy to assign materials to the suitable objects.

As it was mentioned before, *Realistic Visual Style* of 3D visualization shows the assigned materials, which improves working and enables current previewing of the obtained results. It also enables to adjust scales of the assigned textures and finally to set the anisotropic materials position under the suitable angle – for example distribution of growth rings of the wooden boards or waves direction of the corrugated or fluted sheet.

As it was mentioned in theoretical part, for rendering procedure it is suggested to use *Render* Ribbon with all its Panels, enabling setting the suitable parameters connected with light, shading etc.

To obtain the most satisfactory rendering outcomes it is suggested to set *Realistic Visual Style* but also *Perspective Projection* mode, which was described in subchapter 1.10 This will make the model more realistic. To assign the material, there will be applied *Attach By Layer* method, which provides the most efficient materials management.

Materials assigning must be preceded by materials creation, which is time-consuming stage of rendering and requires to set all necessary material parameters (*Color, Transparency* etc.) described in the theoretical part of this book. Fortunately AutoCAD 2012 enables to use pre-defined materials from materials database available in *Materials Browser* dialog window, anyhow they must be processed to adopt them to the conditions of the modeled 3D objects.

The most important windows for materials creation and assignation are the following:

- *Materials Browser* (Fig. 3.83), with database of materials. It is horizontally split into two parts – above set of materials are the materials applied in the current drawing, below them is the set of all available materials in AutoCAD 2012. Access to this window is available using MATERIALS command or by *Materials* Panel, *Render* Ribbon.
- *Materials Editor* (Fig. 3.84), which enables creation of the new materials basing on some materials templates. Access to this window is available using small arrow at *Materials* Panel, *Render* Ribbon.
- *Textures Editor* (Fig. 3.85), which enables setting the proper parameters of the applied textures (scale, rotation etc.). Access to *Texture Editor* is available by *Materials Editor*.

Materials Attachment Options used to assign the created material to the particular layer (Fig. 3.86). Access to this, important dialog is available by *Materials* Panel, *Attach By Layer* option or MATERIALATTACH command.

Fig. 3.83. *Materials Browser* with available Materials Database

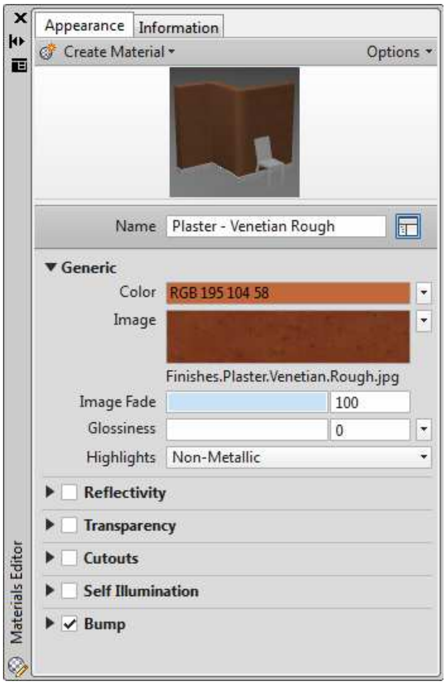

Fig. 3.84. *Materials Editor* dialog window enabling materials creation

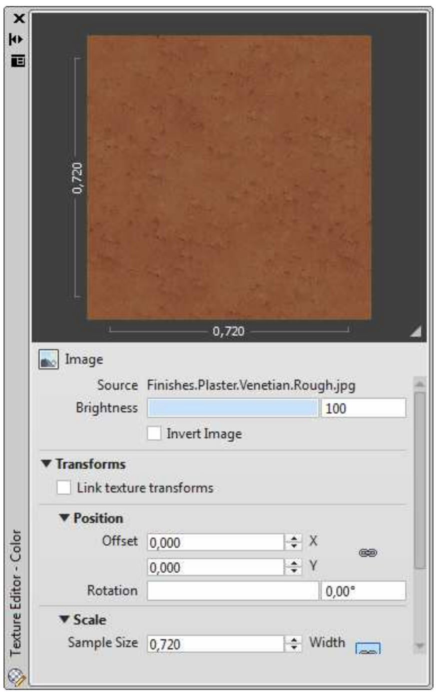

Fig. 3.85. *Texture Editor* dialog window, enabling setting texture parameters

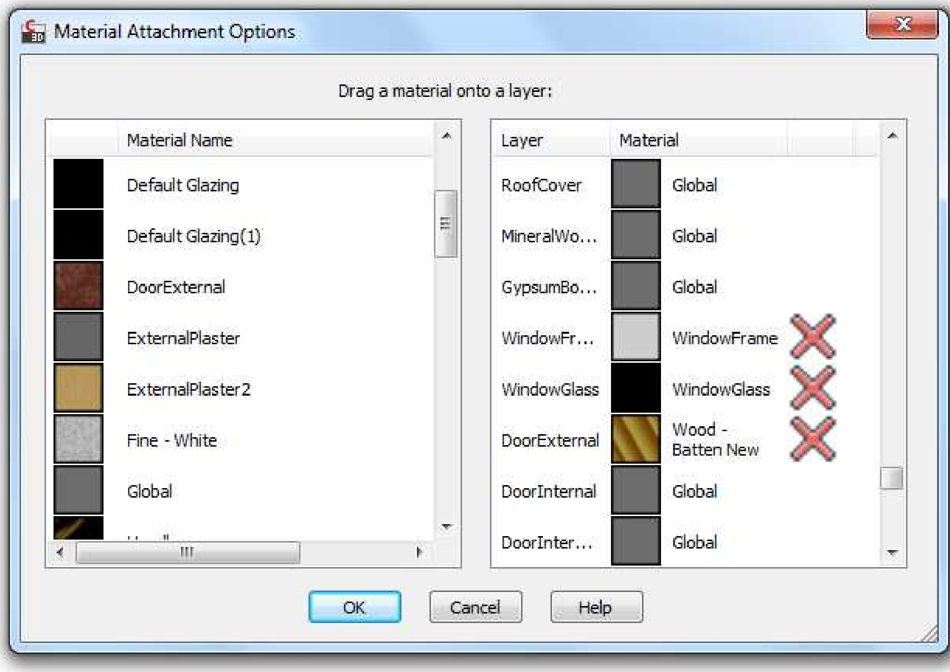

Fig. 3.86. *Materials Attachment Options* dialog window, applied for materials assignation. Left column consists of available materials, right column consists of the available layers

To create a new material, *Create Material* Button of *Materials Editor* (Fig. 3.84) should be clicked, and the suitable name for the material should be given. After this, new material appears in the top part of *Materials Browser* window (creation of new materials is also available using *Materials Browser*). To adjust the texture parameters, texture image should be clicked which will show *Texture Editor* window. All adjustments setting will not be presented here, and it is recommended to test it by monograph readers themselves. The most important feature of this window is the possibility of scale adjustment, which may differ depending on units applied in 3D models.

When all necessary materials are prepared, they should be assigned to the particular elements of the vector model. For that aim *Materials Attachment Options* window (Fig. 3.86) should be opened, which enables material assigning to the particular layer of the model. Assigning procedure can be fulfilled using dragging and dropping method of the material from the left column to the existing layer on the right column. Material attachment should be confirmed with *OK* Button, since now it is possible to preview (in *Realistic Visual Style*) the texture adjustment on the modeled 3D object and if necessary, modify its parameters.

Next stage of rendering prearrangements will be setting the lights, to obtain the most satisfactory results. It is a complicated process, requiring some experience and many tests. For this elaboration, day scenes and night scenes were prepared.

To start working with light and day scenes it is recommended to use SUNPROPERTIES command or click the small arrow on *Sun & Location* Panel. This calls *Sun Properties* window that enables to set the most important sun parameters like *Color*, *Intensity Factor*, *Shadows*, *Geographic Location*, and finally its *Status*.

To set the basic light parameters – *Brightness*, *Contrast* etc. it is suggested to use unfolded *Lights Panel*, where all this parameters are contained and can be defined by the user. Setting the proper light parameters is quite complicated and requires many tests and experience.

Rending is a resources consuming process, thus AutoCAD rendering module is equipped with many features improving its proceeding. Main rendering process features are contained in the *Render* Panel. Rendering procedure can be executed using this Panel, but also using RENDER command. Anyhow it is recommended to configure rendering settings before the process, which can be done in the *Advanced Render Settings* window, which was described in the 1.12 sub-chapter. The most important parameter from the point of view of rendering procedure is image quality, which can be set using *Render Presets List* (or RENDERPRESETS command), that opens the dialog window *Render Presets Manager* with predefined quality adjustments. AutoCAD 2012 offers the following rendering presets: *Draft*, *Low*, *Medium*, *High* and *Presentation*. Of course this presets can be customized using *Render Presets Manager*, anyhow it is not suggested here, and will not be further discussed. Low quality rendering presets (*Draft* and *Low*) are mostly used for tests and previews of expected scenes. They offer quick image processing, that’s why they are often used at the first stage of rendering process. The other attempt is to use better quality presets – *High* or *Presentation*. Obtained results are very effective and attractive, but the rendering procedure is very long and resources consuming. Figures below present example of rendering of the modeled passive house. They are generated using *High* and *Presentation* rendering quality presets.

Hereunder presented renders are showing the modeled 3D house in daylight without any extra light sources. AutoCAD enables creation of extra lights which can also illuminate the objects. They are especially useful in night sceneries. Types of lights are presented in 1.23 sub-chapter and in this part of the elaboration, two light types are applied: *Spot Light* and *Point Light*. *Spot Light* was used for external lightning of the building elevation, and the *Point Light* was used as bulbs for indoor light.

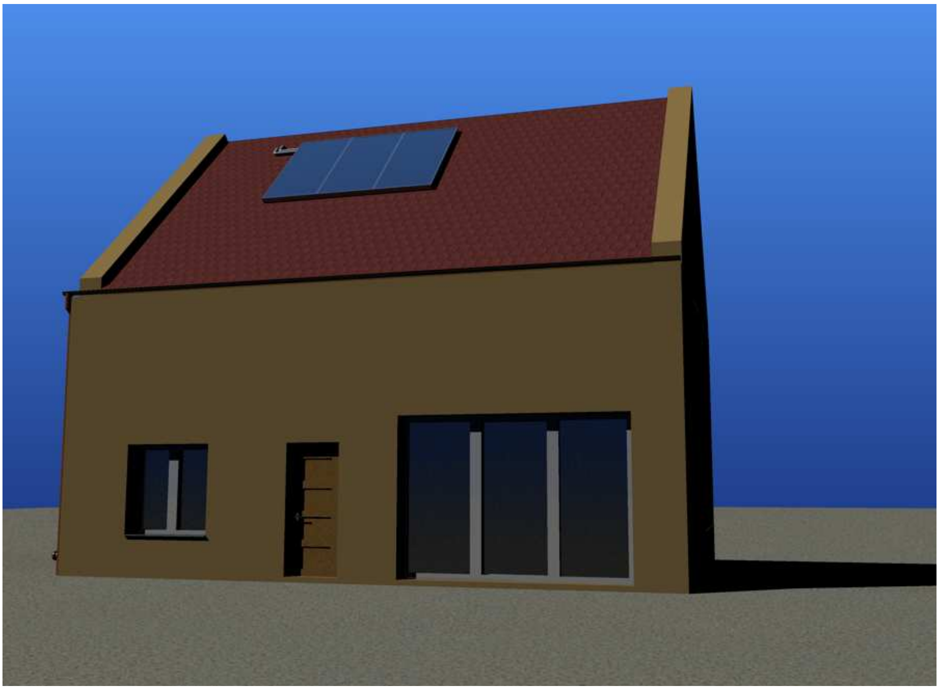

Fig. 3.87. Rendering of the modeled passive house in early daylight

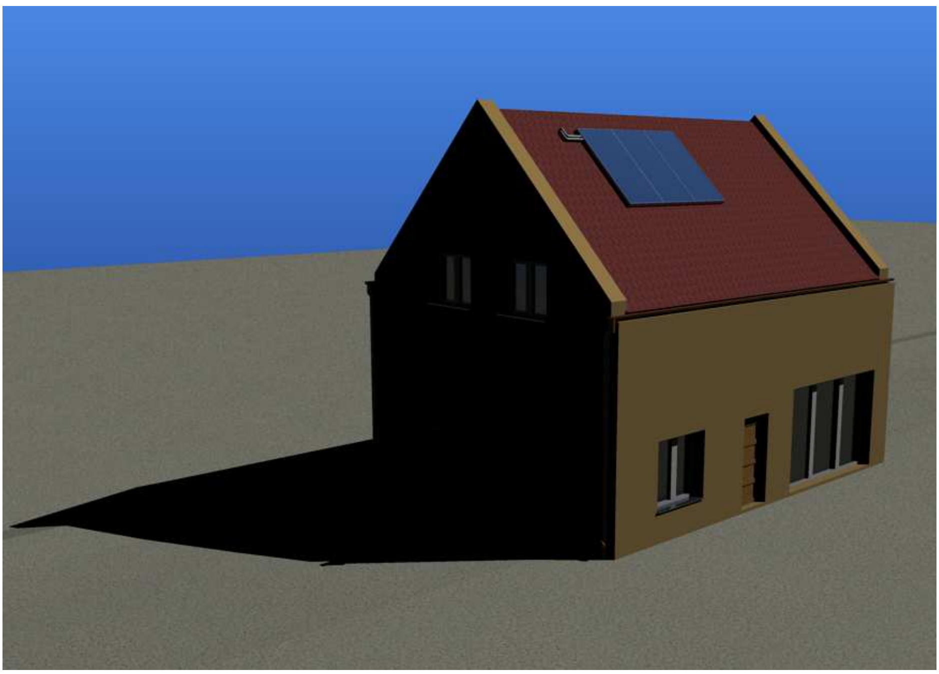

Fig. 3.88. Rendering of the modeled passive house in early daylight

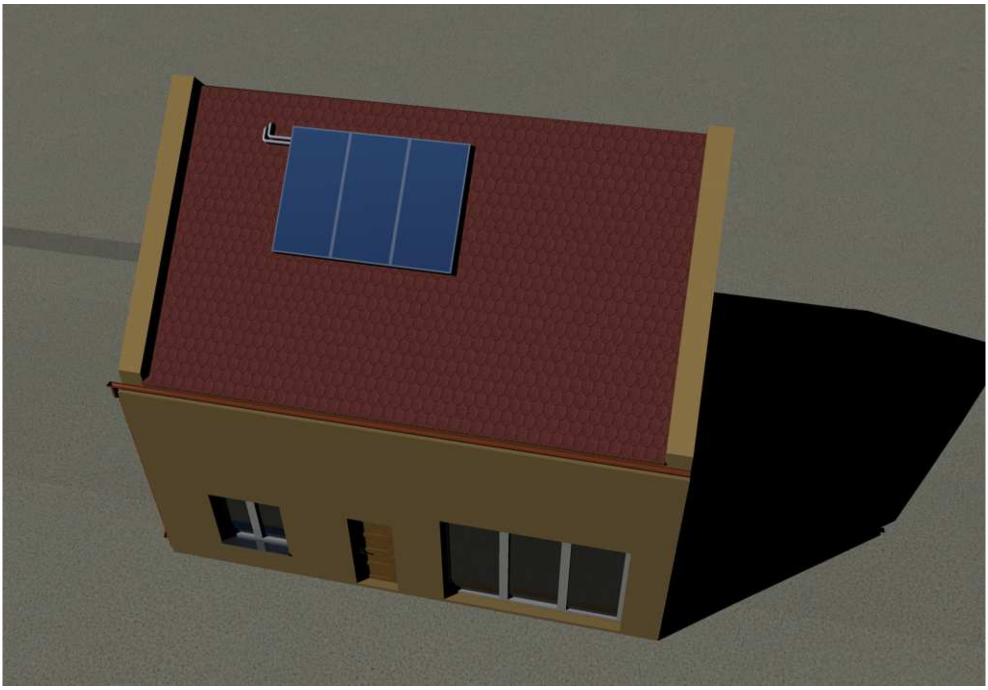

Fig. 3.89. Rendering of the modeled passive house in early daylight

To obtain right night sceneries it is recommended to turn off the sun light and change the background into dark color (in this elaboration it was applied black and dark grey color). Next step is light creation. For that aim *Lights* Panel should be used – *Create Light* Button and then suitable light type should be selected – for example *Point* (or POINTLIGHT command), and then such a sub-command appears:

Specify source location <0,0,0>:

which enables to set the position of light source. After the position of light source (bulb) is established another sub-command appears:

Enter an option to change
[Name/Intensity/Status/shadoW/Attenuation/Color/eXit] <eXit>:

where light parameters can be set: *Intensity*, *Status*, *Shadow*, *Attenuation* and *Color*. After the light is created, it is represented by an icon which appears in its position (Fig. 3.90). Since then, light becomes a typical AutoCAD object with parameters that can be edited in *Properties* window (resembling typical vector objects). Similarly to the other AutoCAD objects, it means that once created *Point Light* can be moved and copied to the other parts of the drawing (for example to other rooms).

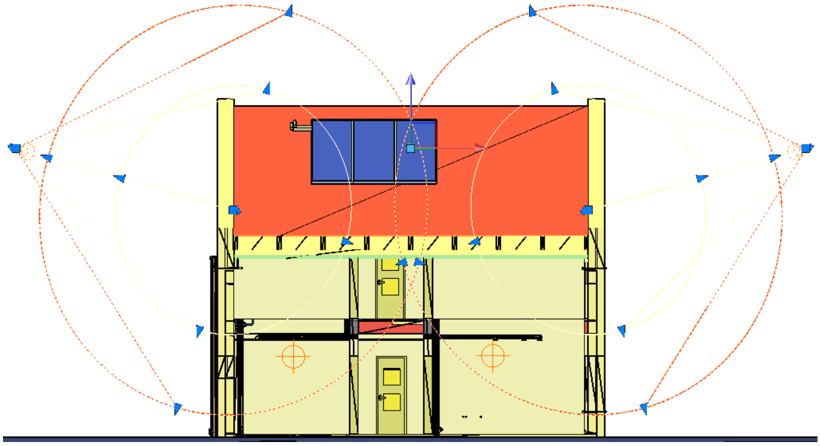

Fig. 3.90. Setting the *Point Light* and *Spot Light* for rendering procedure

Other type of light used in the rendered scene is a *Spot Light*. It can be generated using *Spot Icon* of the *Lights* Panel or SPOTLIGHT command. Comparing to the previously presented light creation, *Spot Light* requires to specify the location of the source:

Specify source location <0,0,0>:

and the destination:

Specify target location <0,0,-10>:

and other parameters like before:

Enter an option to change
[Name/Intensity/Status/Hotspot/Falloff/shadoW/Attenuation/Color/eXit] <eXit>:

The most important among them are *Hotspot angle* and *Falloff angle* visible at Fig. 3.90, which can be also modified using Properties Window or even by dragging and dropping. Representation of i is a torch-shaped icon visible at Fig. 3.90 and Fig. 3.91.

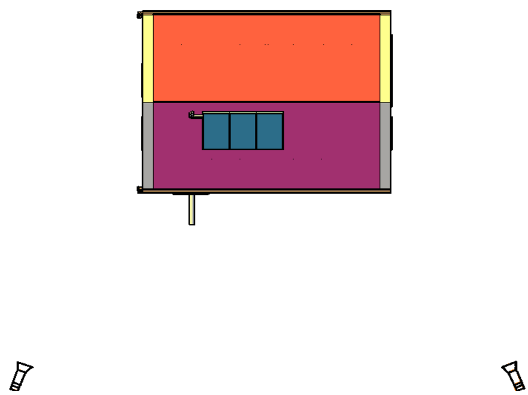

Fig. 3.91. Setting the *Spot Light* for rendering procedure

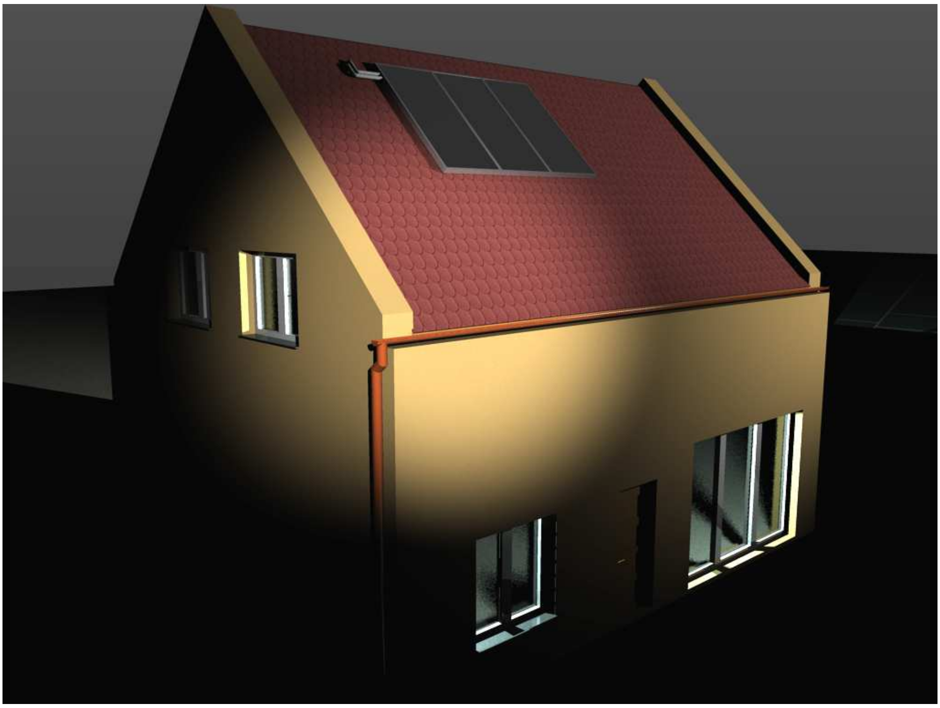

Fig. 3.92. Night scene of the modeled passive house

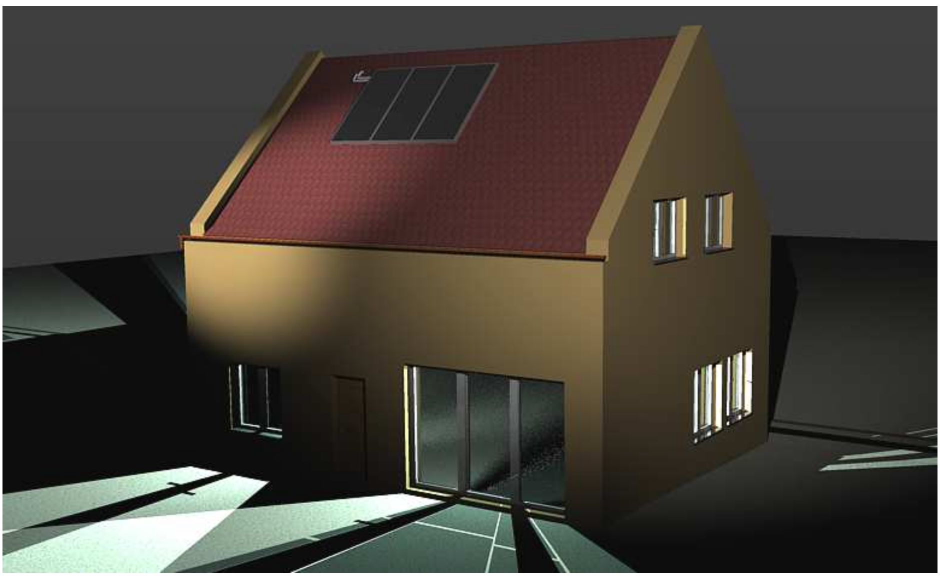

Fig. 3.93. Night scene of the modeled passive house

Presended at the previous page figures 3.92 and 3.93 show night scenes of the modeled passive house. The building is lighted from external by two *Spot Lights* and from the inside by *Point Lights* (bulbs).

The last scenes presented in this monograph are the indoor scenes. Figure 3.94 presents the cross section of the whole building with all visible rooms. Figures 3.95 and 3.96 show the ground floor, the boiler room and all sanitary equipment elaborated within preparing of the 3D model. Indoor scenes are rendered using extra lightning, which was caused by the fact that default light (from the sun) was not able to illuminate indoor elements due to barriers in the form of the external partitions.

Presented indoor scenes visualize some details of building construction – roof rafters, stairs and partially ventilation system (Fig. 3.94). Figures presented on the next page show details of boiler room equipment, pipes distribution and fittings mounting.

Fig. 3.94. Cross-section of the whole passive building

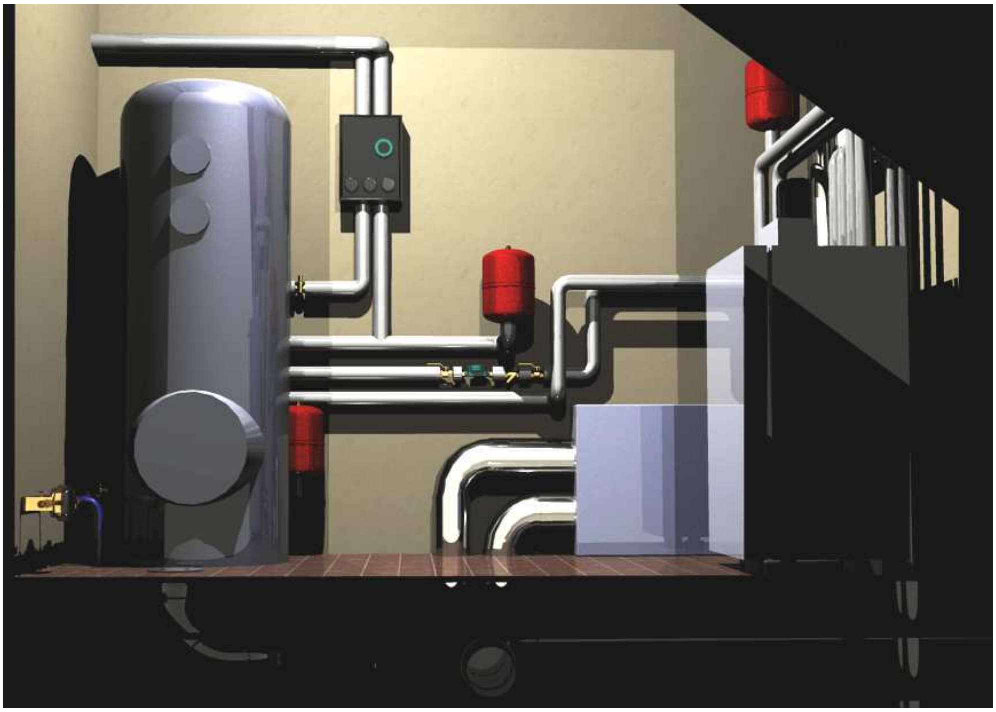

Fig. 3.95. Cross-section of the boiler room

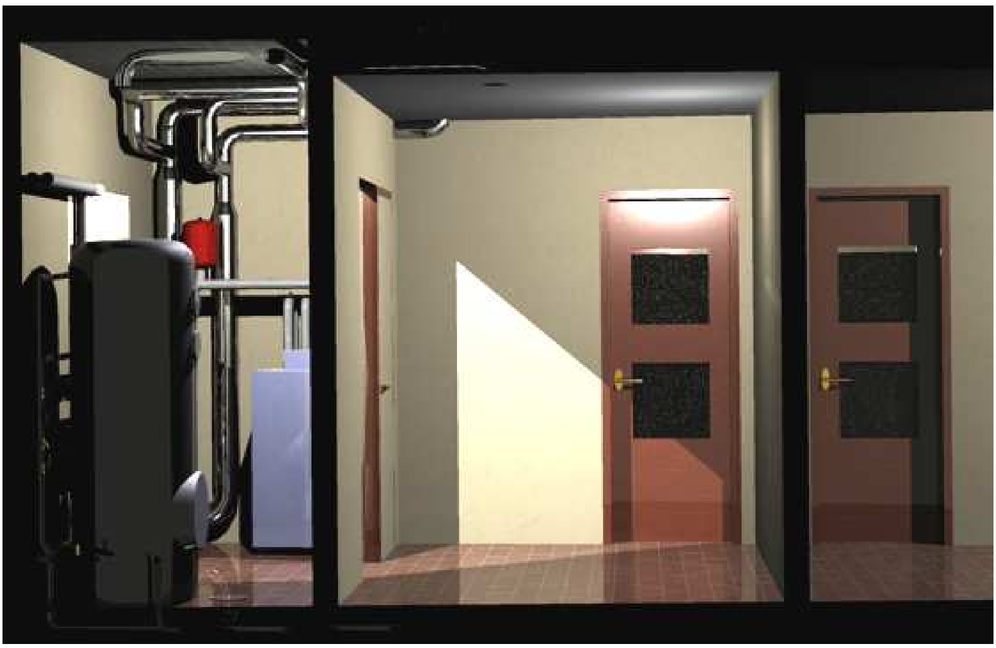

Fig. 3.96. Cross-section of the ground floor

4 Summary

The idea of this elaboration was to present AutoCAD 2012 as useful tool for visualization of engineering objects in the discipline of Environmental Engineering. For that aim the special attention was paid onto its 3D modeling potential.

The first chapter presents the interface of AutoCAD 2012 and its most important features for modeling of 3D objects. The particular input of this chapter was focused on the coordinates systems which are available in AutoCAD 3D space. A lot of place was devoted to the visualization of 3D objects together with the most representative *Visual Style – Rendering*.

Second chapter is a description of the 3D objects available for drawing in three dimensions. It focuses on the presentation of 3D wireframes, surfaces and the solids and their most important parameters and modification abilities.

Third chapter is a model of a passive house, which is a representative and up-to-date object in the branch of Environmental Engineering. Model proposed in this elaboration is not the design, anyhow there are applied solutions which are suggested for the passive buildings and are solved according to the passive buildings philosophy, described in the following elaborations (*Wnuk*, *2006; Wnuk*, *2007*). The special attention is put onto modeling of sanitary installations together with ventilation-heating, water supply and sewage disposal system. Significant part of the presented the passive house is the model of solar and heat pump system.

All modeled objects and elements are visualized in the form of the rendering scenes which are imitating real photographs and may be applied by the passive house builders as visualization.

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