The Unofficial LEGO Advanced Building Techniques Guide

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The master builders tips and tricks book

Contents

Introduction

What makes a building technique to be advanced? There is no easy answer, advanced is just the way we, adults, feel some building techniques because they do not appeared, at least do not appeared widely, in the officials LEGO® building instructions. Most of these techniques are discovered and then used and developed by adults fan of LEGO (AFOLs) or by LEGO designer in the LEGOLAND™ parks. These techniques generally results in a wide array of interesting design and offer a details resolution which was unavailable previously using classical building. Jake McKee precise, in his book "Getting started with LEGO Trains", that advanced building techniques "enables not only the creation of specialized shapes and angles, but also various non standard dimensions" and "add a wealth of [...]designs."

This late assertion alone is far enough to justify to make a compilation of all these advanced building techniques. That's the goal of this document. The author goal is not to appropriate to himself these techniques - you are encouraged to check the credits page at the end of the document - but to make a comprehensive collection of tips and tricks, which are widely available on the internet, but which are also, unfortunately, widely scattered and, due to this spreading, mostly unknown and endlessly and uselessly re-discovered.

2007, Didier Enjary

# Vocabulary and geometry about LEGO plates and bricks.

The following illustration presents the 2x4 brick's top and bottom and the 1x4 brick's bottom. The top is covered by studs (referring to some patents, it could be also named knobs). The bottom is filled by tubes or bars depending of the brick size[1].
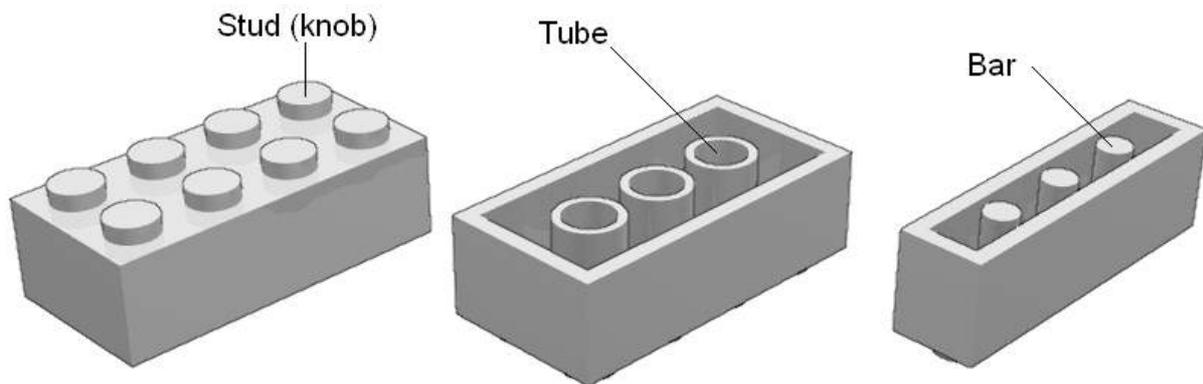
Plates are thin bricks. Technic™ bricks present passing through holes in their side and the studs is scooped out : we talk then about hollow studs.
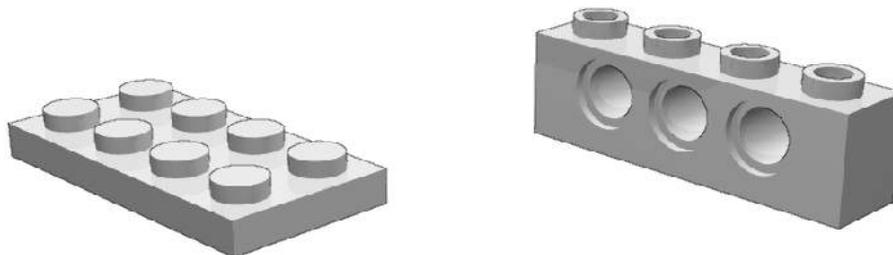
Conventionally, a LEGO Unit (L) equals the 1xn parts width: 1L=8mm[2]. The L is commonly avoided. We will also use a subdivision of the LEGO Unit that we call LDU[3] : 20 LDU = 1L.

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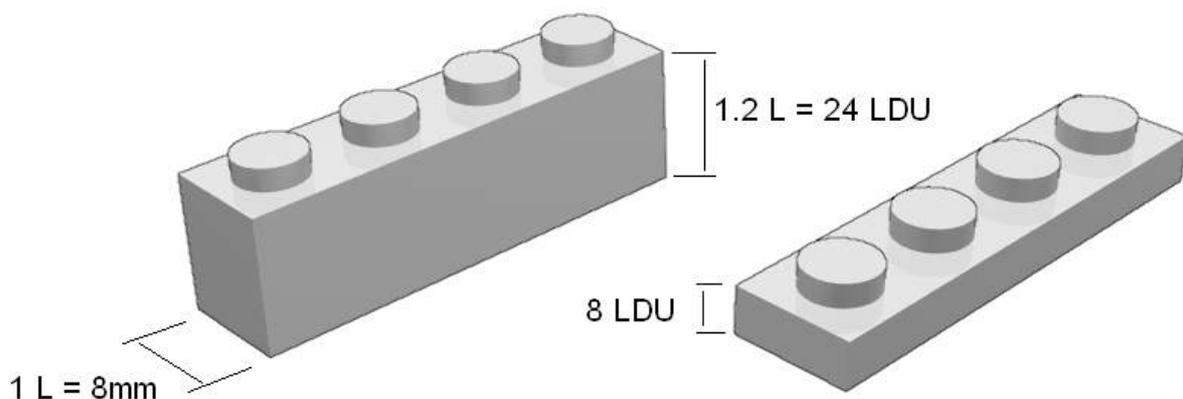
[1] Some transparents parts are not filled at all.
[2] 8mm equals 0.315 inches which is sometimes approximated to 5/16 (0.3125)
[3]LDU stands for LDraw Unit. LDraw is a standard used in CAD applications to describe LEGO parts. One LDUequal 0.4mm and can be approximated by 1/64 inches http://www.brickwiki.org/index.php/LDU

Some people are also used to talk in term of "stud" instead of LEGO Unit. This can lead to confusion as the diameter of a stud is 0.6 "stud". Others will use "brick" in this same place. Hence, **when talking about geometry of parts**, LDU should be prefered as it allows to deal with whole numbers and not fractions, and doesn't lead to confusion with any idiomatic vocabulary.

Measuring a 1xn brick, we see the ratio between height[4] (24LDU) and width (20LDU) is 1.2 (6/5). The plate height (8LDU) is a third brick height (24LDU).

The stud diameter and tube (outer) diameter is 12 LDU and is height is a bit higher than 4 LDU. That are also the size of inner diameter of Technic brick axle holes.

Bars' diameter is 8 LDU. That's the same of the inner diameter of hollow stud.

[4] Not taking into account the studs

Chapter 1

SNOT

General SNOT

SNOT. Isn't that word funny? In fact not a word but an acronym standing for "Stud Not in the Top". The LEGO building toy use a building process which consist in stacking parts of various sizes and shapes on top of each other, vertically. SNOT is the name we give to any building tip resulting in the studs of parts not pointing up. SNOT techniques represent a large part of advanced building techniques.

SNOT is made possible thanks to the 5:2 SNOT ratio and to SNOT parts.

The 5:2 SNOT ratio is a direct consequence of the bricks and plates geometry :
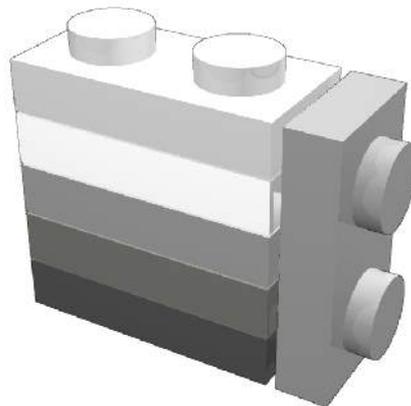
5 plates height (5x8=40 LDU)   equal   2 LEGO units width (2L=40LDU)

One can guess this relationship is not a simple coincidence but a will from the LEGO parts designers. Of course, this ratio fits when multiplying : 10 plates height equals 4L parts length, 15 plates height (5 bricks height) equals 6L parts length and so on. Hence, the 6:5 ratio is a direct consequence of the 5:2 ratio.
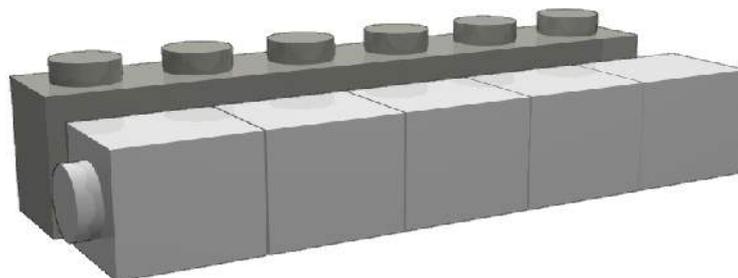

The 6:5 ratio

Stud-out SNOT

The 5:2 SNOT ratio is quite useless if you can't link efficiently the rotated group of parts. SNOT techniques are all about this. Thankfully to specific parts, beginning with SNOT is not so intricate. For instance it exist bricks with studs on their sides:

- Brick 1x1 with 2 studs on sides
- Brick 1x1 with 4 studs on sides
- Brick 1x4 with studs on side
- Brick 2x4x2 with studs on sides
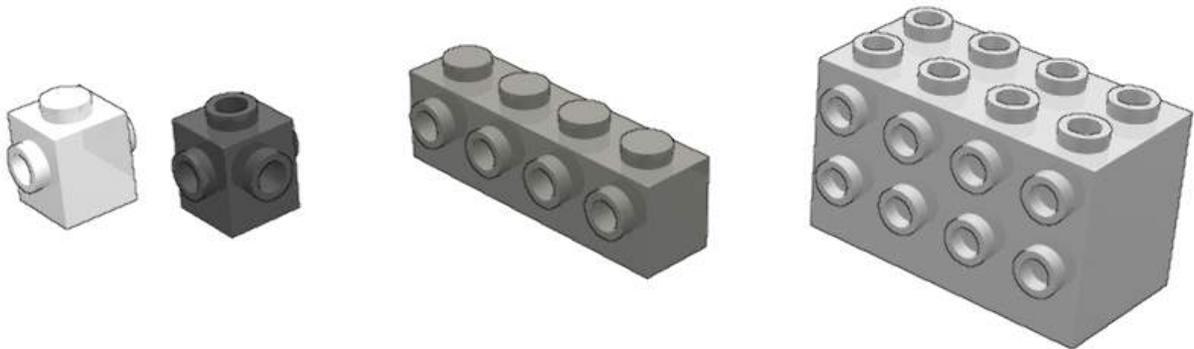
The basic SNOT scheme is then easily made. These parts with studs on their side are "SNOT parts".

Bricks with studs on sides are not the only SNOT parts. It exists also a lot of modified parts, among them brackets.
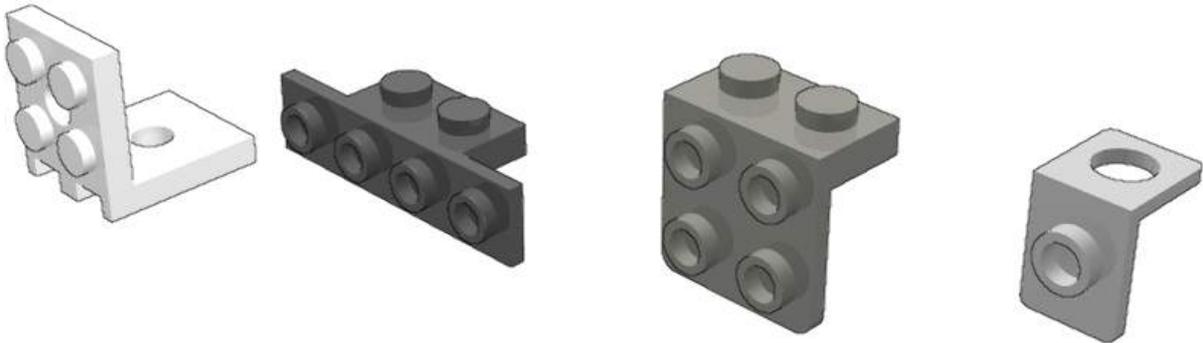
With a bit of curiosity, you will discover that some elementary buildings are efficient when dealing with SNOT. For instance, the Technic 1x1 brick and the half stud pin come rapidly to an equivalent (and unavailable) brick 1x1 with one stud on the side. In fact, every Technic brick equipped with half pin is a potential SNOT part.
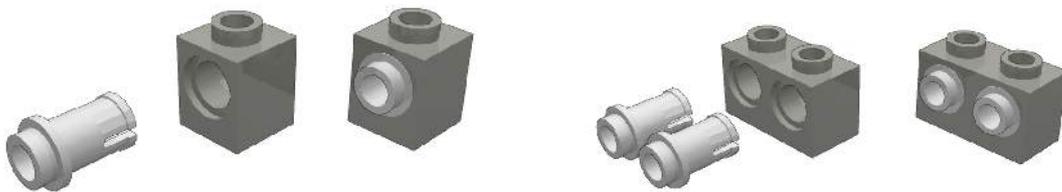
The half pin part is more than a strictly half pin. It's a half pin at an end plus an hollow stud in the other end. Another part allow a similar building, which is the Technic axle 3 with stud but you will notice a slight offset due to the axle lip.
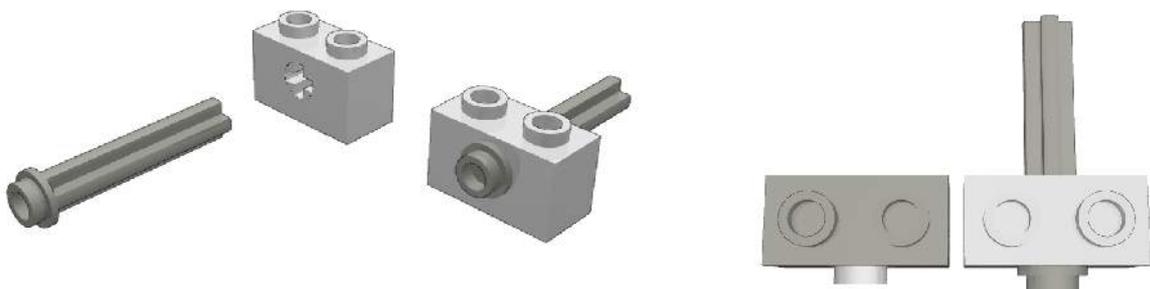
Stud-in SNOT

Until now, the SNOT we have presented is a "stud-out SNOT". The stud is not on the top, the stud is on the side. In a similar way, we can define a "stud-in SNOT" where a tube, a hole or a socket intended to receive a stud is placed on a side.

There are stud-in SNOT parts
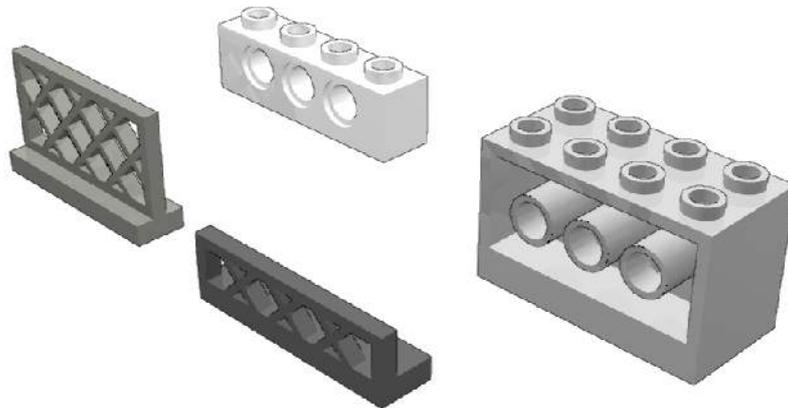
Among them, 1xn Technic bricks allow stud-in SNOT with a lateral 10 LDU (half-stud) offset[5] but, due to overlapping effect, only with smaller parts. The 1x1 Technic brick and 1x2 Technic brick with 2 holes (AZMEP Technic bricks) are noticeable exceptions.
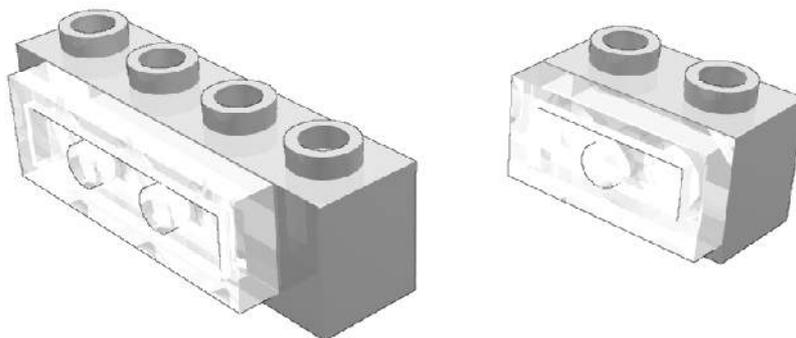

The 1x4x1 fence does not present the offset nor the overlapping effect . The 1x4x2 fence present an unexpected 7 LDU negative offset.


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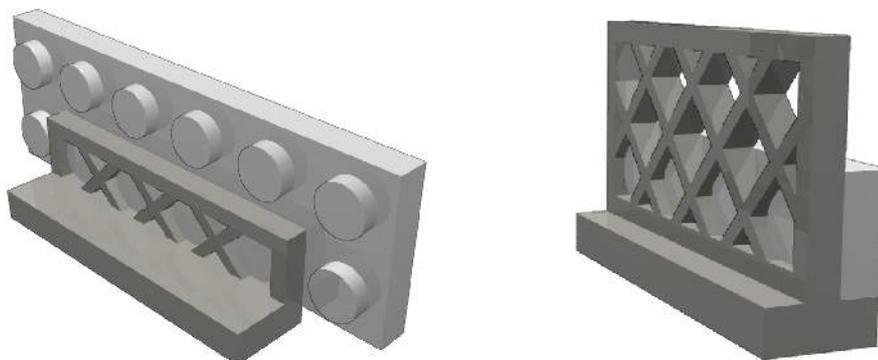
[5]Offseting is the subject of Chapter 2.

SNOT Examples

SNOT is not only a subject of study for itself but has practical uses. The followings chapters will covered some examples. One very frequently encountered SNOT building is the following, to create letterings (see chapter 3) or large windows for passenger trains. As you can see, it uses both stud-out and stud-in SNOT building :
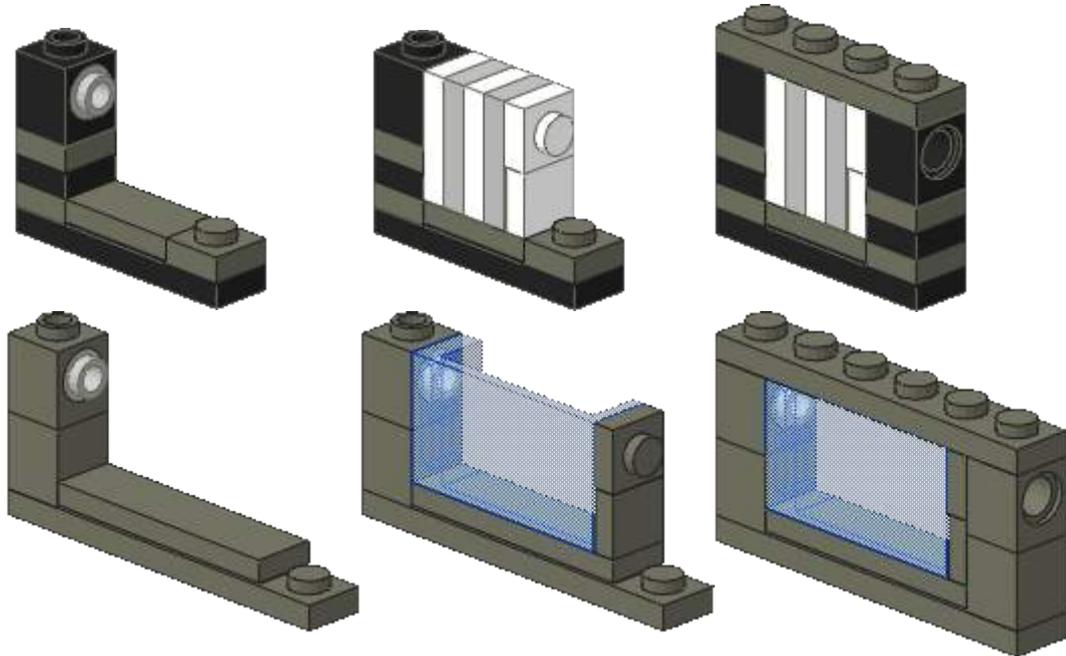
Employ of the 6:5 ratio is represented by this train front bumper, original idea by James Mathis.
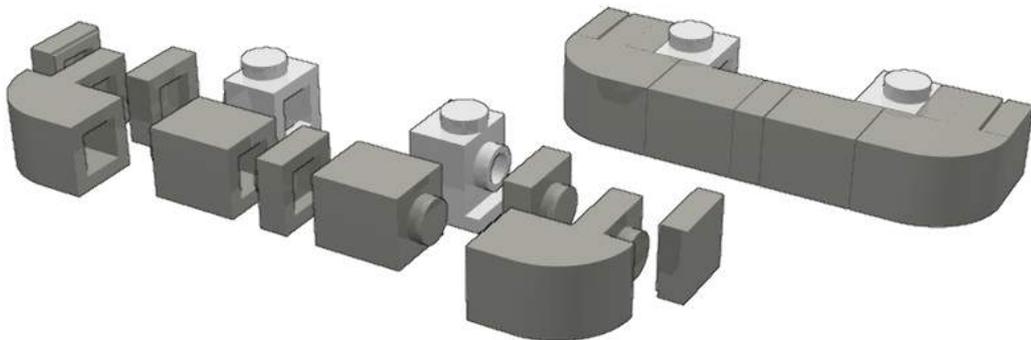
SNOT 180

Some parts exist both in the normal and inverted version. For instance slope bricks, even some arches. But some design will need the use of an inverted part which does not exist.
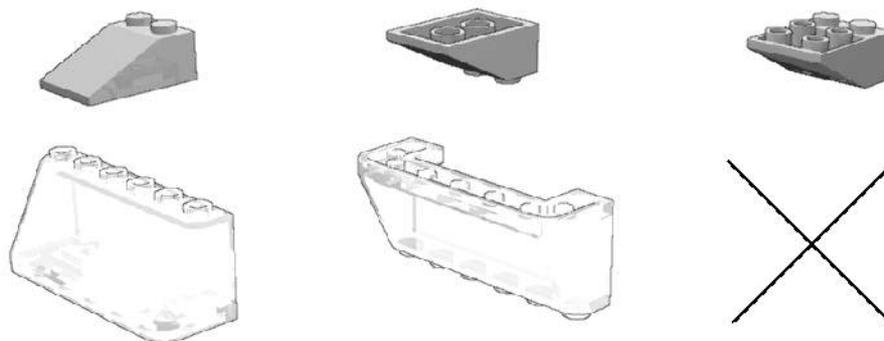
Until now, SNOT has been limited to 90 degrees rotations. SNOT 180 allows you to invert parts. SNOT 180 is then what you need.

2 x SNOT 90 = SNOT 180

SNOT 180 is sometimes as simple as combining two SNOT :

*Combining two stud-out SNOT* : these examples are 24 LDU high (1 brick)
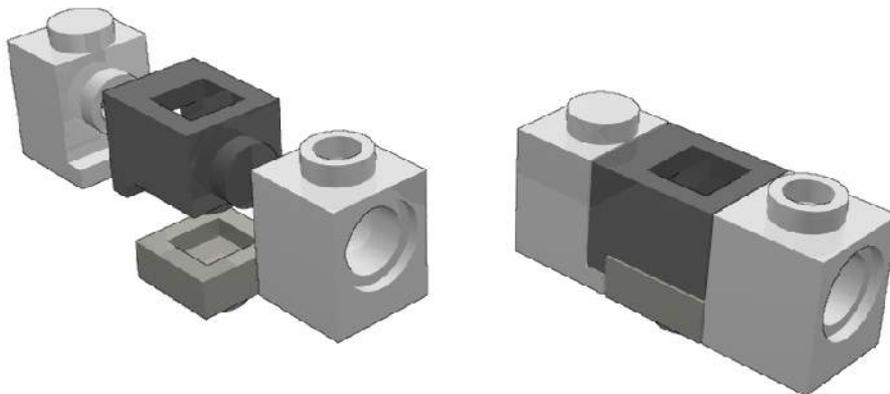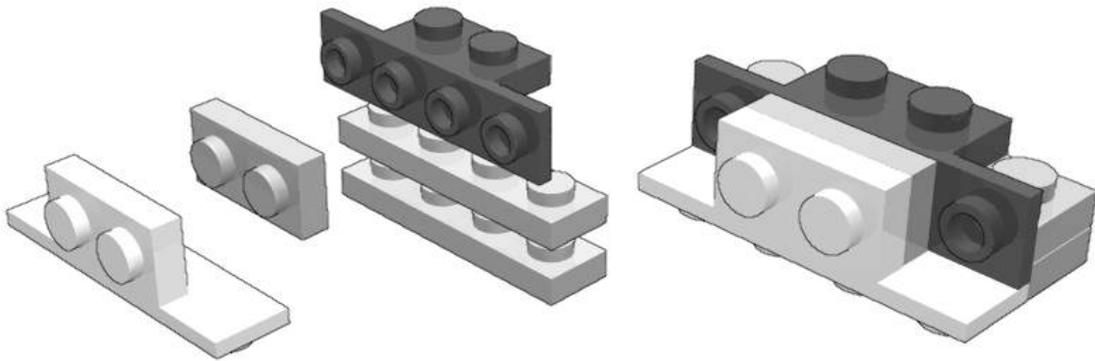
*Combining stud-in and stud-out SNOT*
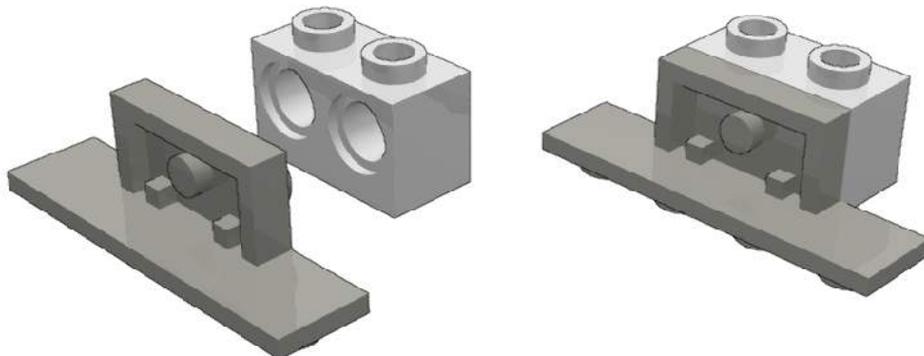
SNOT 180 parts

Some parts geometry allow direct inverted building, presenting tubes or studs on two opposed faces.

Studded SNOT 180 parts
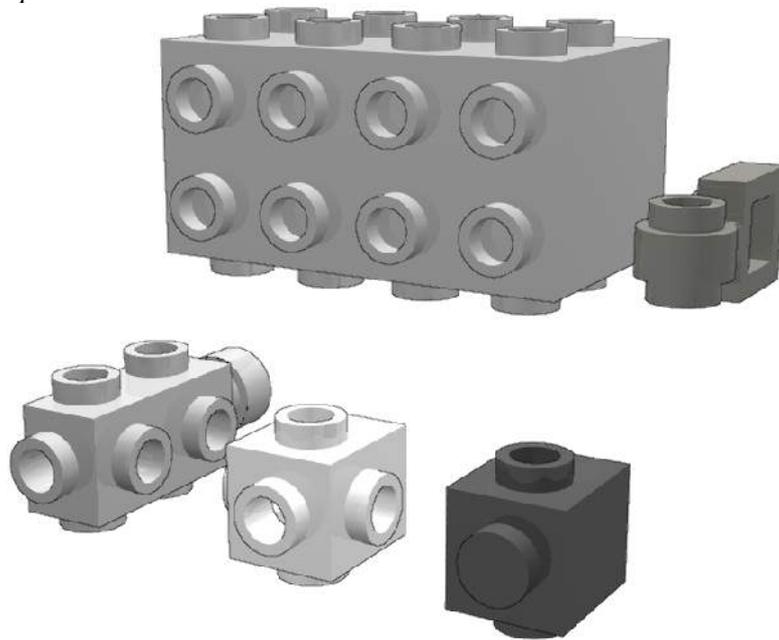
The 2x4x2 brick with studs on sides is used on official LEGO models for instance to create snotted undercarriage in Santa Fe's sets. It is 40 LDU high (5 plates). The others bricks with studs on sides in the illustration are 20 LDU high

Two different type of 1x1 with clip exist. The left plate with clip, which is discontinued, is thinner than the new one. When stacking plates on both sides, the resulting width is respectively 20 LDU (one stud) and 24 LDU (one brick).
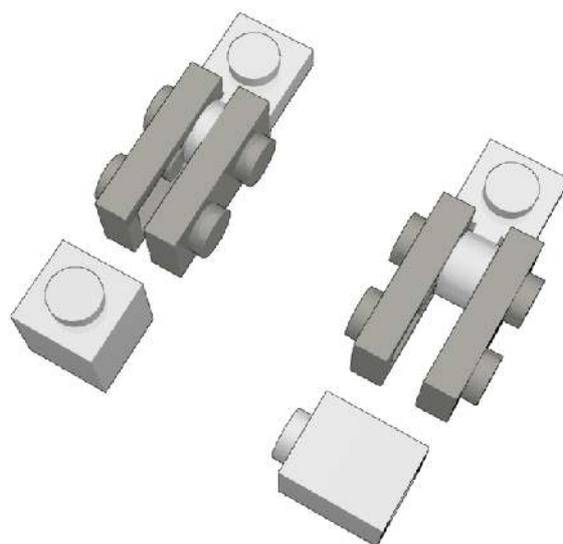
Passing through holes parts

The Technic plates are passing through holes parts :
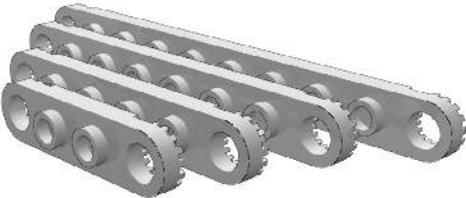
Technic bricks, lift arms, beams and Clickit™ ring are also examples of passing through holes parts but their thickness (12 and 20 LDU) is different from a multiple of a plate width.
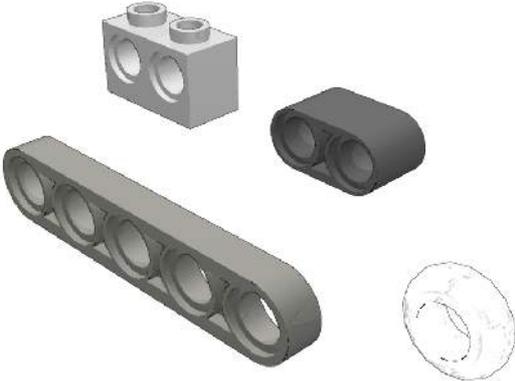
The SNOT 180 technique has been originally named Knob inversion by Steve Barile. James Mathis has designed these applications :

Train cab window :
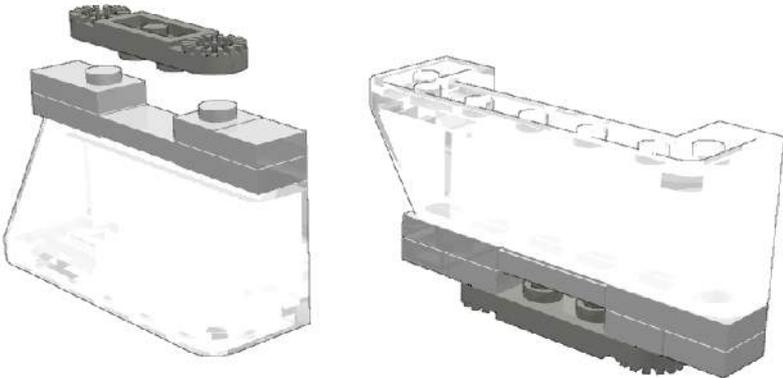
Oval train door window :
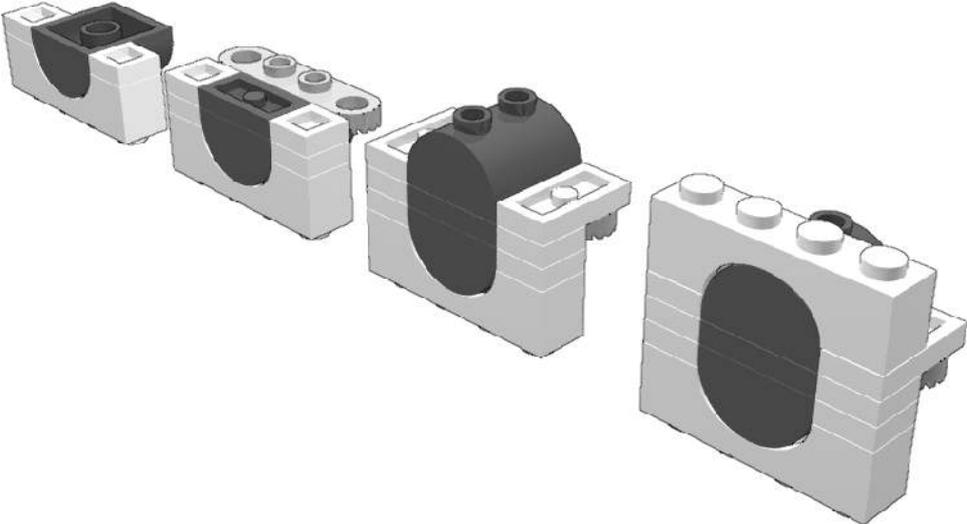
SNOT 180 connections

Some parts are part of a link system different from the stud and tube system and can be combined in an inverted way :

Hinges :
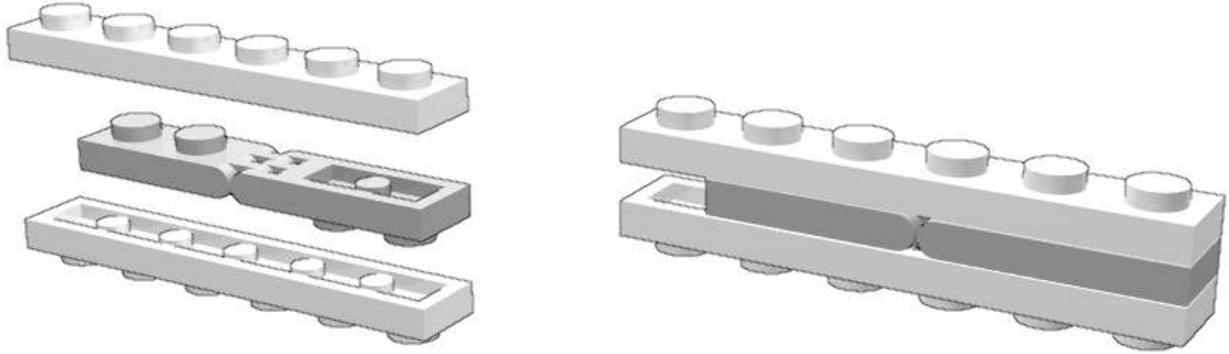
The resulting building is 24 LDU high. The same building is possible with plate and brick click hinges but then you will face respectively a 12 and 28 LDU height.
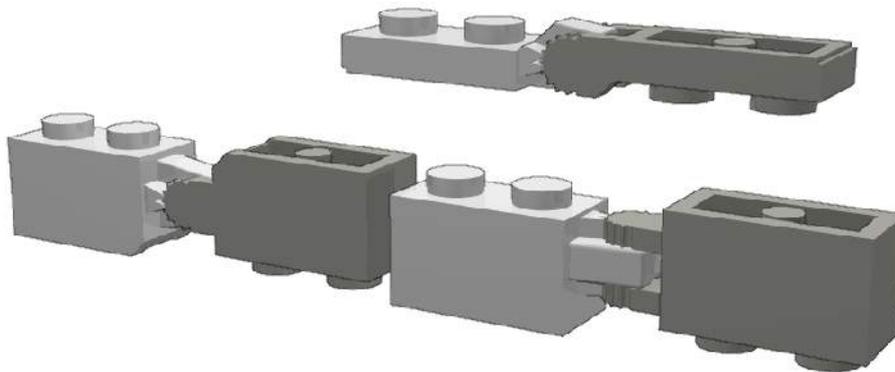

Clip and Bars :

Timothy Gould's building :
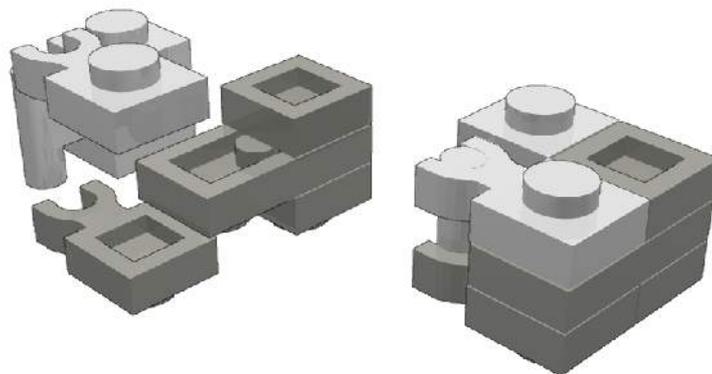
SNOT 180 with Technic parts

Axles

This building work only for bricks bigger than 1xn bricks.
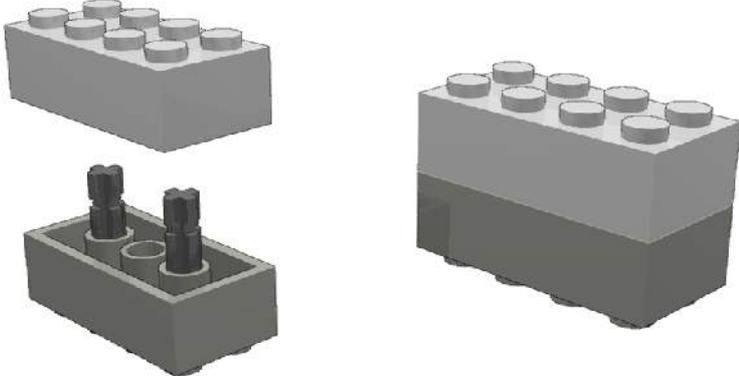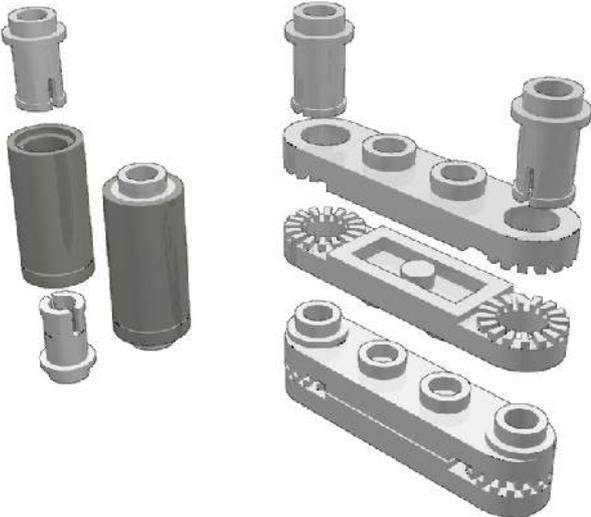
which are respectively 48 LDU high (2 bricks) and 16 LDU (2 plates) high (or 18 LDU if using the half pins studs and not the Technic plate ones).

Half pins
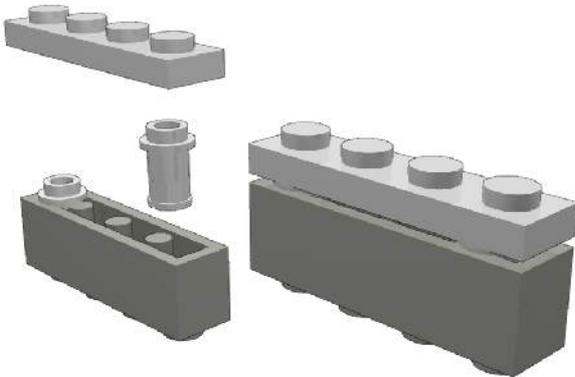
With a 34 LDU height.

Pins : with a 28 LDU height
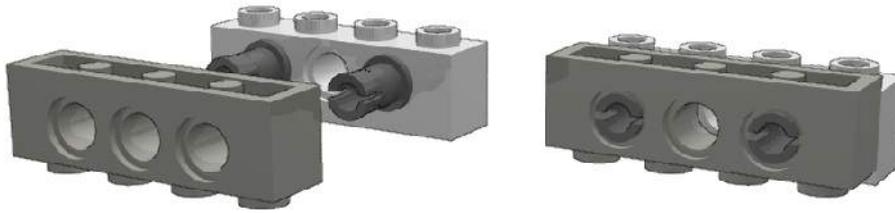
with a 50 LDU height
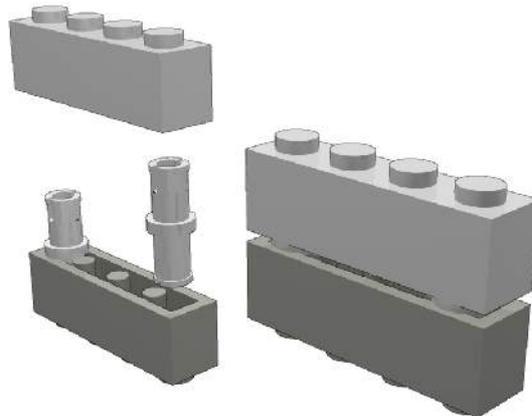
Others SNOT 180 buildings

Plate inversion with levers (control stick) is the thinnest SNOT 180 building with a 16 LDU height.
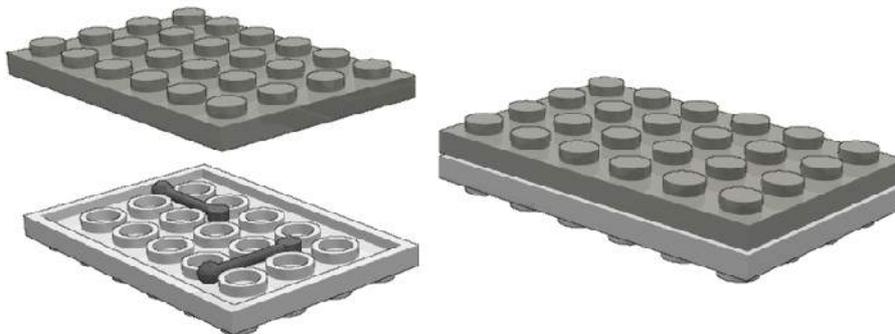
This building is limited to large plates. It can be reinforced by increasing the number of stick. It can also be improved using cut Technic tubing.

Pony ear technique and ToPLESs

The pony ear technique is a very particular SNOT building technique in this way that it applies to thin parts (plates, tiles) and requires no SNOT parts.

The original pony-ear technique consists in placing a 1x2 plate vertically between the studs of a 2x4 plates. This building is used in classic official castle sets to represent ears of brick built horses.
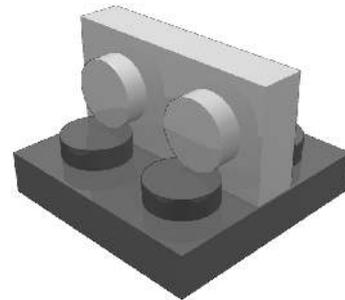
As the plate is rotated to a vertical plan, it's a SNOT technique even though it does not use specific SNOT parts. The pony-ear technique is quite limited by his definition and applications. The following ToPLESs technique is a natural enhancement.

ToPLESs stands for Tile or Plate Located between Enough Studs. ToPLESs is an advanced building technique that has been developed directly from the pony ear technique. It has been theorized by Erik Amzallag. The following is entirely based on its presentation he made during a French AFOL meeting on 2004.
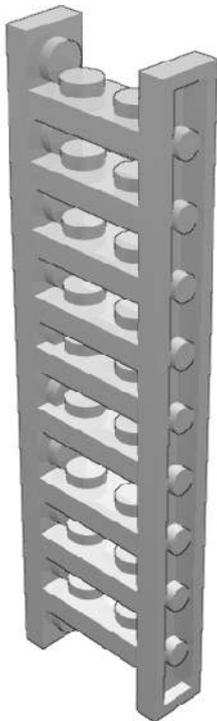
ToPLESs has appeared in official sets such 311, 609 and 613. In these official LEGO set, the use of this technique is very limited: only one or two plates or tiles are concerned. Adult fans use this technique to create thin walls, fences, ladders, beams, etc and more heavily as mechanical structure (footbridge, roller coaster).

ToPLESs is subdivided into P-LESs and T-LESs, where P stands for Plate and T for Tile.

P-LESs present a major drawback. As studs are a bit thicker than 4LDU, the P-LESs stacking is in theory impossible due to overlapping effect. In practice, there are two situations. Whether the number of overlapping studs is low (for instance in the pony-ear technique) and then it cause no trouble, whether the overlapping studs is consequent and then it cause the plates to be bended. This drawback at least as one major advantage : the connection is very tight.

We can bring with two solution to the P-LESs drawback :

- Offseting : the studs are no more facing but alternate, so there is no more overlapping.
- T-LESs : tiles are stud less plates, so there is no more overlapping.
 and the connection is still tough.
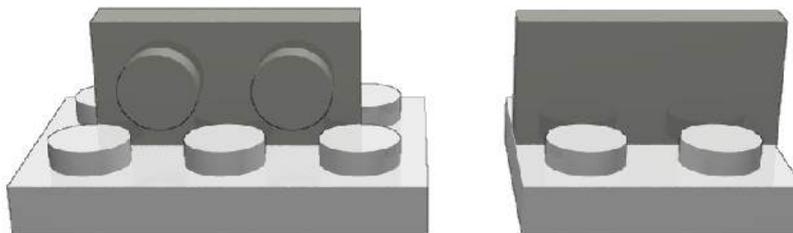
Various SNOT

GSNOT

The G in GSNOT is for Gary (McIntire), the inventor of this building. At least, click hinge bricks have finally find a use.
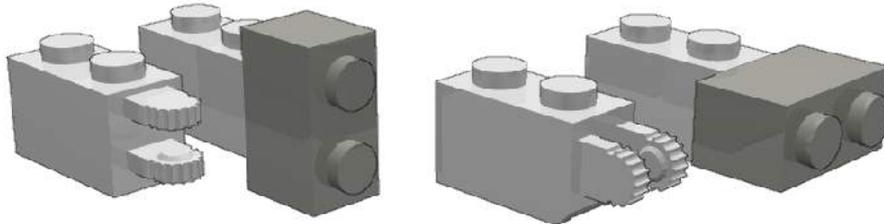
Combining three GSNOT :
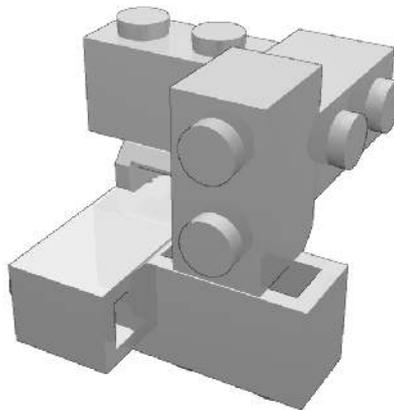
DSNOT

DSNOT is based on the hinge top part. The building is tight and allow rotation with friction. Further buildings could be imagined using hinge top part with other hollow stud part. As for GSNOT, DSNOT term has been coined by Jon Palmer and stands for Didier SNOT.
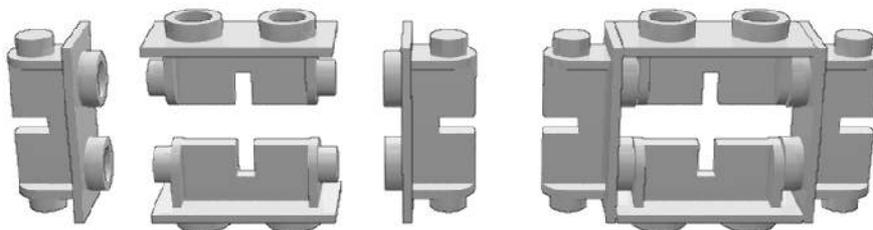
Chapter 2

Offseting

AZMEP

The following is partly based on Reinhard "Ben" Beneke presentation he has made during BrickWest 2003.

AZMEP is a german acronym (aus zwei mach eins Plättchen) for the half stud offset. That's, with SNOT, the second most important advanced building technique. As for SNOT, it exists dedicated parts : AZMEP parts.


Among them, the most popular is certainly the jumper plate. So popular it has several names : center plate, jumper plate, jumper, 1x2 plate with one stud...
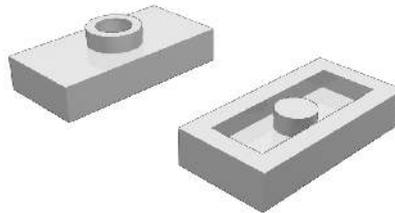
If we compare the jumper plate with the common 1x2 plate, we can see :

a) the top presents only one stud, which is centred: this allow AZMEP (half-stud offset) stacking.
b) this stud is hollowed : this allow regular stacking.
c) the underside is unchanged : the jumper plate behave this side like a regular 1x2 plate.
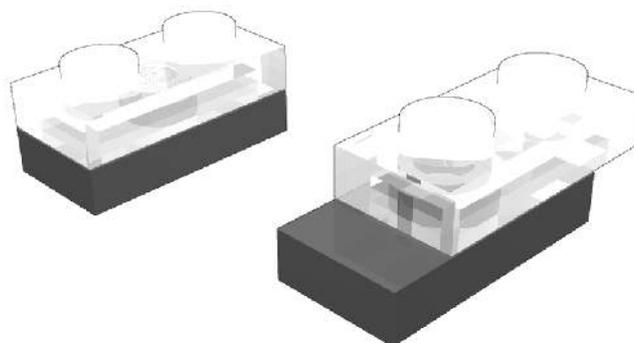
Regular and AZMEP stacking

Others tricks and parts allow to create AZMEP buildings :

Stud-to-tube trick : Rather than stacking the underside tubes between the studs in a classical way, you stack them directly on the studs. This technique works fine only if the plate you stack is bigger than the one she is piled on, because of edge effects.
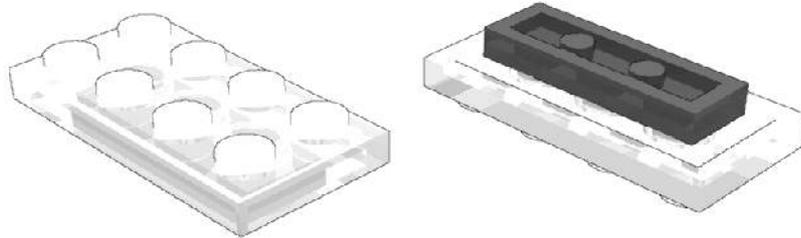
Tube to hollow stud trick : This trick is very similar to the previous one and can be applied to narrower parts. It consists in stacking underside bars directly in the stud. Thank to Technic parts and some System parts, the hollow stud is widely available.
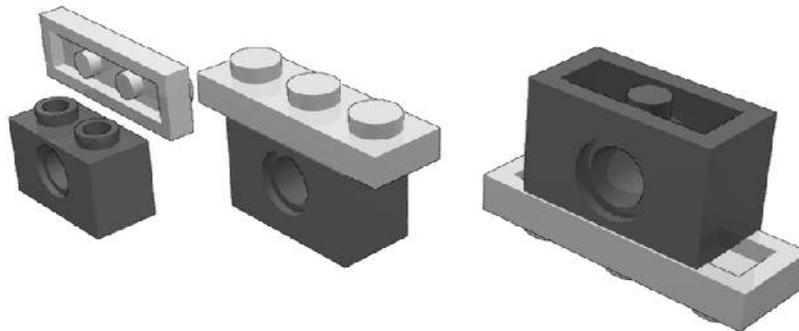
AZMEP Technic bricks : In most Technic bricks, axle holes are placed, on the side, between the studs. That's not the case in the two AZMEP Technic bricks where they are aligned, allowing AZMEP buildings :
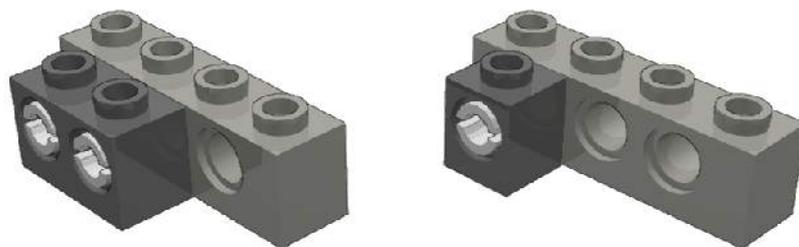
AZMEP bar/arm and clip :
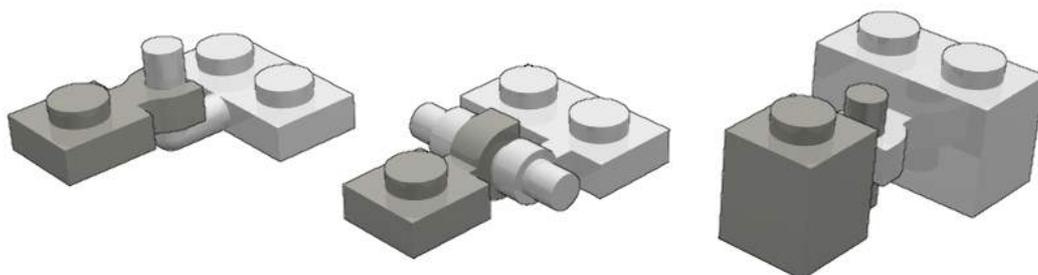
AZMEP hinge :
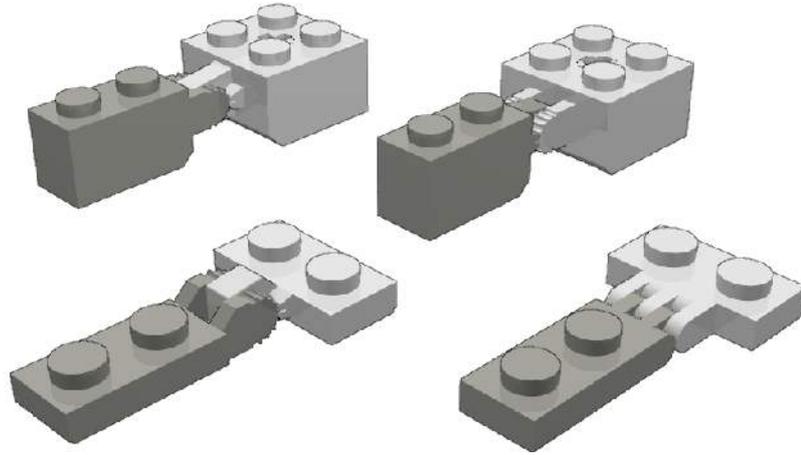
AZMEP is a tool to switch between the odd and even sizes in the LEGO building, for instance to create 7-wide trains or 5-wide cars.

Tenths-stud offset

AZMEP is a half-stud offset (10 LDU) and is made possible by specific parts. It's the most commonly used offset, but could we imagine a smaller size offset? Others parts present odd dimensional characteristics with 6 or 4 LDU offset. Among them, these SNOT parts.
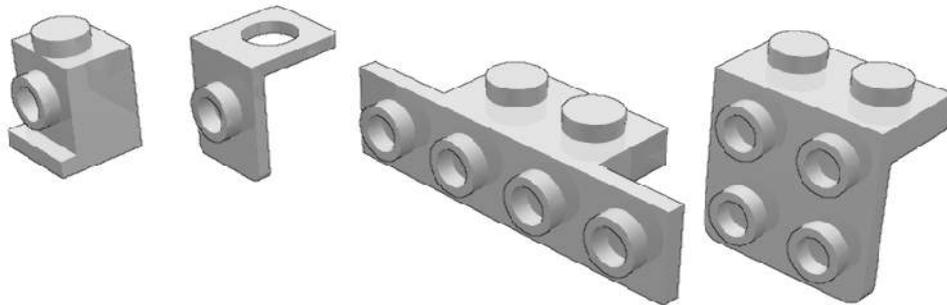
These offsets and stud-out SNOT allow tenths-stud (2 LDU) offset. Jason Railton has listed an exhaustive buildings collection similar to this one :
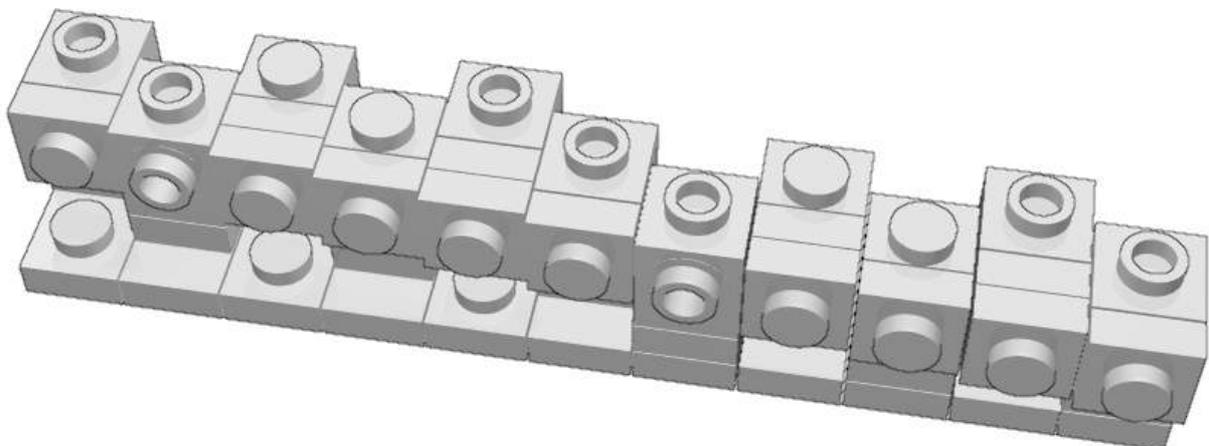
The jumper plate provides a 10 LDU offset, SNOTted plates provide an 8 LDU offset and the headlight brick provide a 4 LDU offset. The following illustration will help you in building the increasing offset.
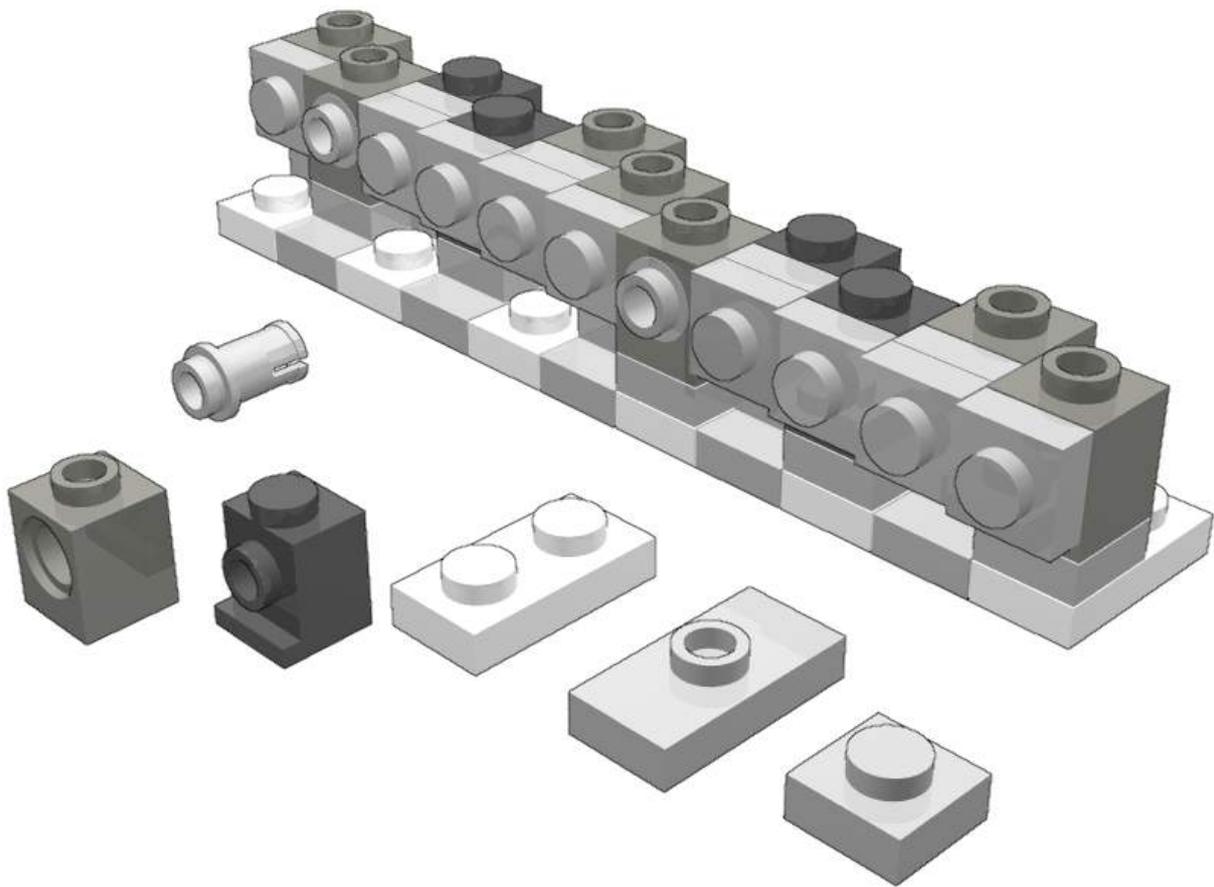
The original building by Jason Railton uses hinges and brackets.

Continue offset

Until then, we have dealt with discrete (in the mathematical meaning) offsets : half-stud, tenths-stud. Even though LEGO is mainly based on discrete system, some parts allow continue offsets :
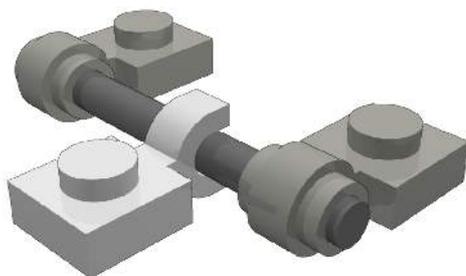
Bars / Arms and Clips   *Technic Axles and Bricks*
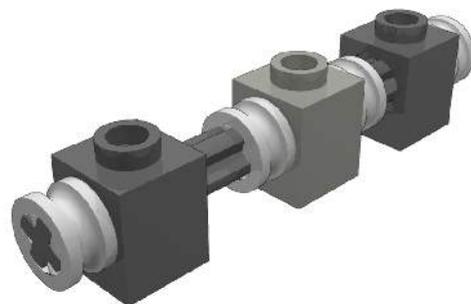
Marakoeschtra's wall

Real brick built walls present a typical pattern where bricks alternate with thin joints. Could we recreate this pattern with LEGO parts ? The combination of SNOT and continue offset leads to an elegant (and parts consuming!) solution :
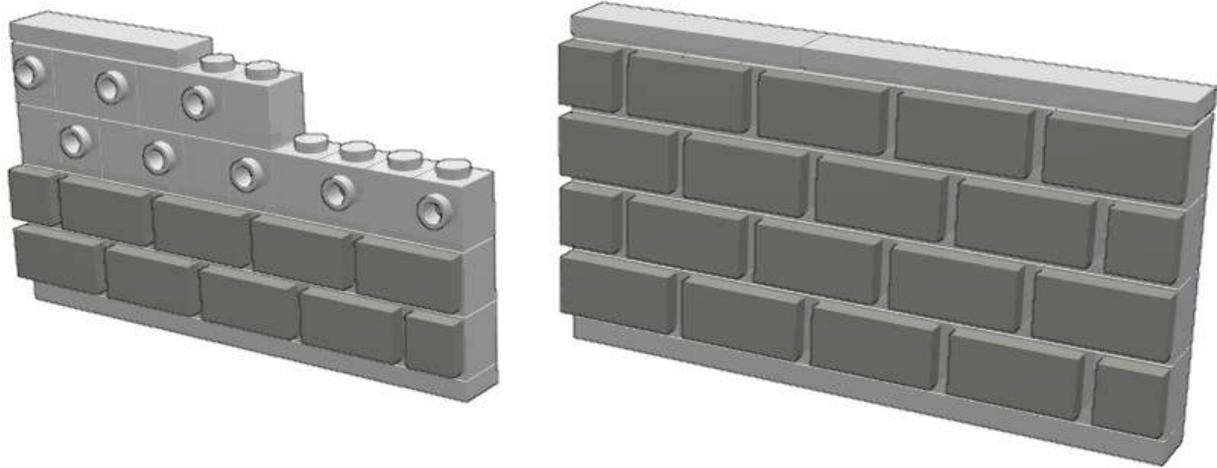
The 1x2 tile have this specificity they don't have underside tube. They can freely slip on the studs, allowing a continue offset. This specificity is used for this wall, where the tiles are stacked on the studs with an offset of 5 or 10 LDU. The vertical joints are 5 LDU when horizontal ones are 4 LDU thick.
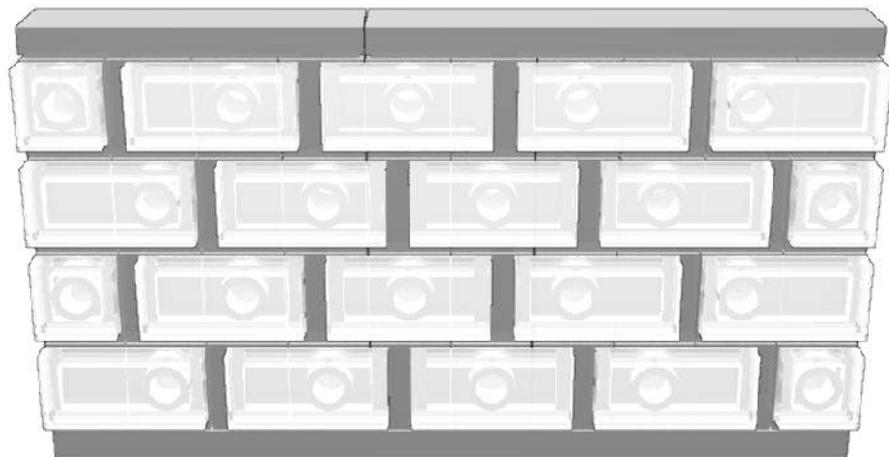
Alternative buildings :
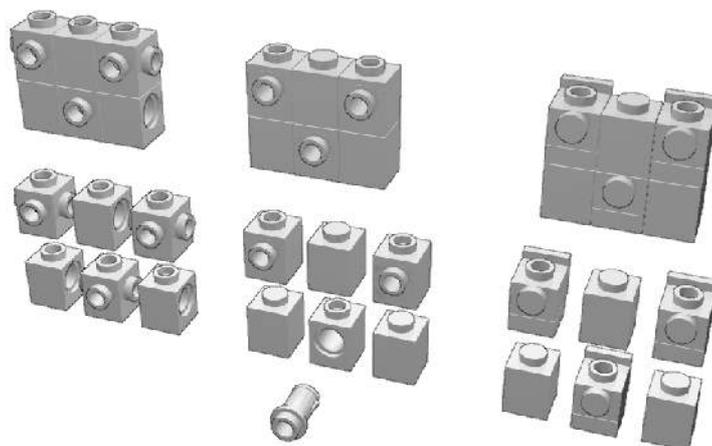
Letterings

Introduction

You may need to put some brand, name (short text) or graffiti on the sides of your rolling stocks, coaches or engines, shuttles and fighters or buildings. Let's study some of the various ways to perform such decoration.

Stud-out mosaics

You can use a "stud-out" mosaic technique. The LEGO Company proposes a font based in such technique on the 226 idea book.

Smaller font based on this technique can be achieved. They are easy to use and all the letters and figures can be represented. But this font is not really small. For instance, the following font is 100LDU high and the bars of letters are 20LDU wide. This technique is not an advanced one.
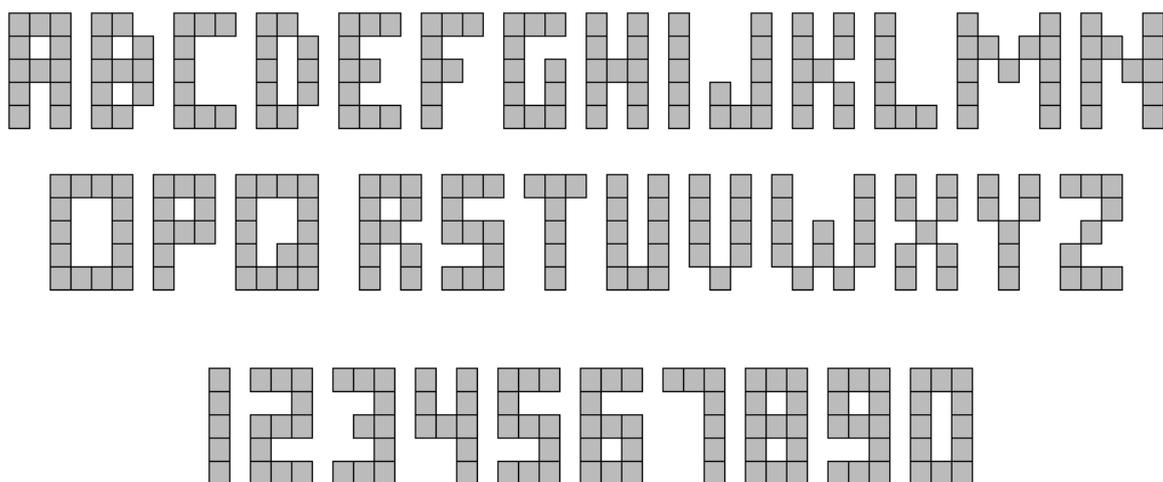
100LDU sized upper case letters and figures

In some case, you could satisfy yourself with smaller letters and figures:

ABCDEFG HIJKLM
NOPRRSTUVWXYZ
1234567890

80LDU sized upper case letters and figures

abcdefghijklmn
opqrstuvwxyz
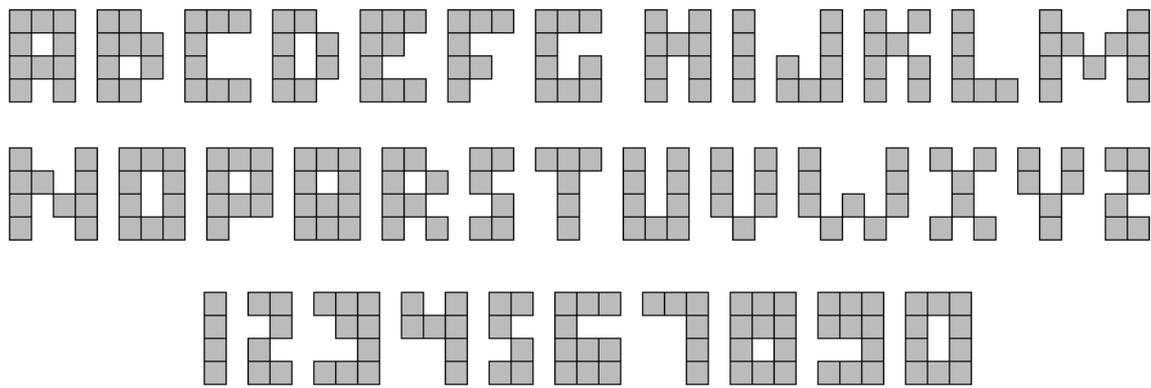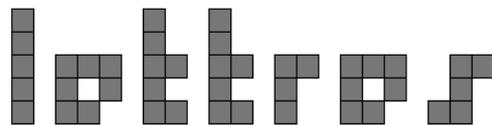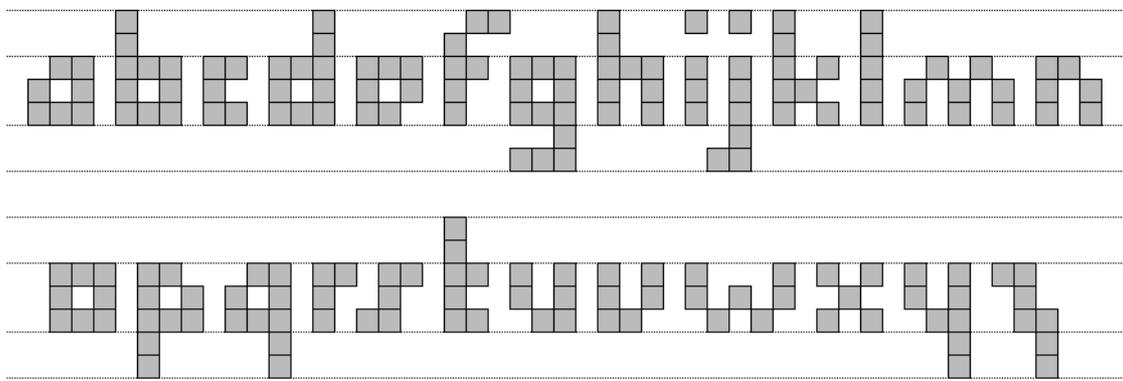
60LDU sized lower case letters

CDHIJKLMN
OSTUVWXY
1234567890
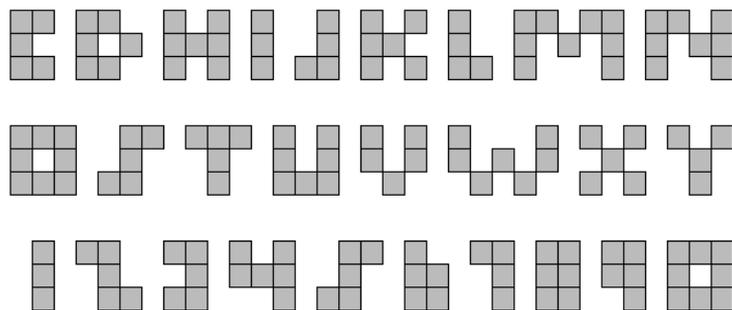
60LDU sized upper case letters

These latter examples show some 60LDU sized letters can be achieved but are not really aesthetically satisfying. Then, we need to scale down the building.

Stud-up mosaic

Stud-up (classical way of stacking plates and bricks) mosaics letters are smaller. (40 LDU)
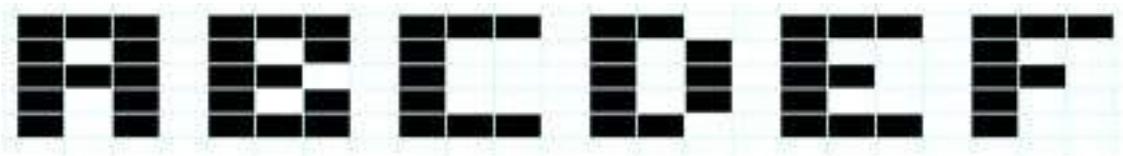
The structure of this font is identical to the previous 100LDU stud-out font.

The horizontal bars of the letters are 8LDU wide instead of 20. The vertical bar of letters is still 20LDU wide. As a consequence, letters may look wider than tall or bolded.

Both stud-out and stud-up fonts particularly fit well with non-rounded and non-diagonal letters such : E,F,H,I,L and T but also with figures and rounded letters which can be squared (A,C,G,J,O,P,S,U). Some good looking results can be achieved with diagonal letters such N and X.

Stud-up letters are smaller, but it's not a great advantage because they are only vertically shortened. That does not allow in practice a better (smoother) dithering. However, this is sufficient to apply into some LEGO creations.

James Mathis' SBB pattern and CFF pattern on Swiss Re44 engine.

SNOTized mosaic letters

This kind of font consists of a 90° rotated stud-up mosaic letters. Due to the rotation, the horizontal bar of the letters are then 20LDU wide and the vertical ones 8LDU wide. The font is 80LDU tall. As you can see in the pictures below, this lettering implies the use of SNOT Techniques. In fact, that's a direct application of the basic SNOT techniques.
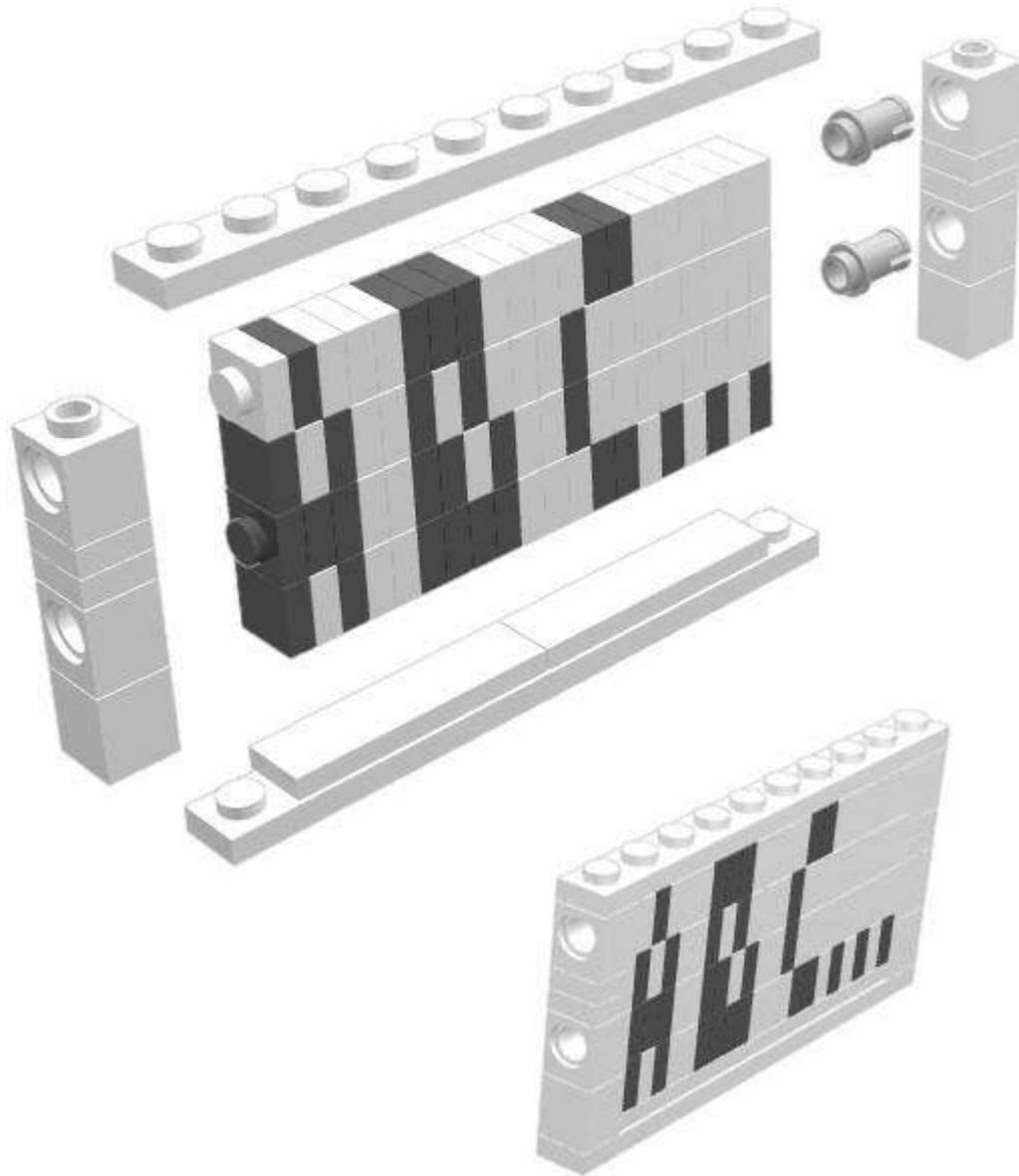
Mathis letters

The Mathis letters are an improvement to the SNOTized letters, which lead to a 56LDU tall font. Mathis improvement consists of creating up and down 8LDU thick lines without adding SNOT building difficulties.
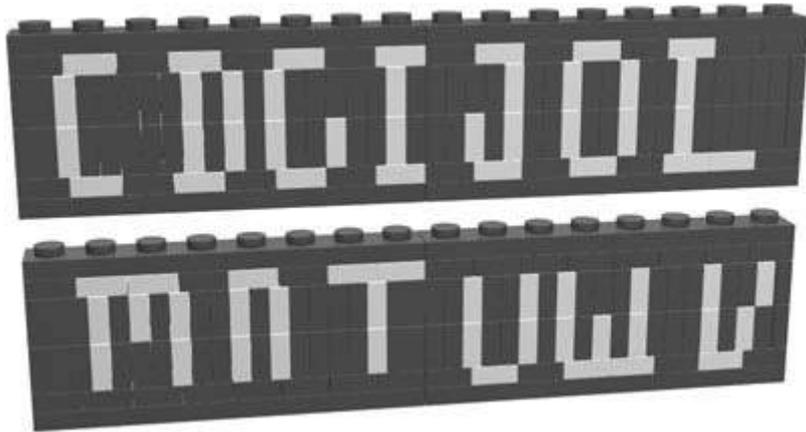

Examples of Mathis letters

Mathis font pros are the small size and thin bars of the letters. But the font is not complete, for instance you can't realize the letters with mid level bars such the B, F , H, P, R or A and E. So our goal is not totally achieved.

SNOT font

These letters present both vertical and horizontal 8LDU thick bars but are harder to build. SNOT skills are required. The great advantage with SNOT building is that letters with mid-level bars can be easily represented contrary to Mathis letters. The building structure is based on the 5:2 fundamental SNOT geometry ratio. A drawback to SNOT lettering is that the letters are, at least, 2L deep. This may prevent you from using such a technique in 6-wide train applications or internally detailed models. At least this technique is well appreciated by adult builders:

[Chips trailer](#) by Jeff Van Widen

SNOT Letters table

Chapter 4
Diagonal striping

Real locomotives, rolling stock, trucks present a great variety of liveries. To recreate this colour scheme in LEGO models is challenging. Focusing on diagonal striping, using slope bricks is an answer at first glance. They are available in large variety of colours, and with their inverted counterparts in various angle values.

Slope bricks striping

One plate height (8 LDU) offset.

Unfortunately, normal and inverted slopes can not be placed side by side in the classical way, because of an overlapping effect. The commonly used answer to the overlapping effect is the use of one plate height offset. Some rapid theoretical calculations show that the gaps between slope bricks vary from 3.6 to 1.2 LDU. They are reasonably good for LEGO® models.
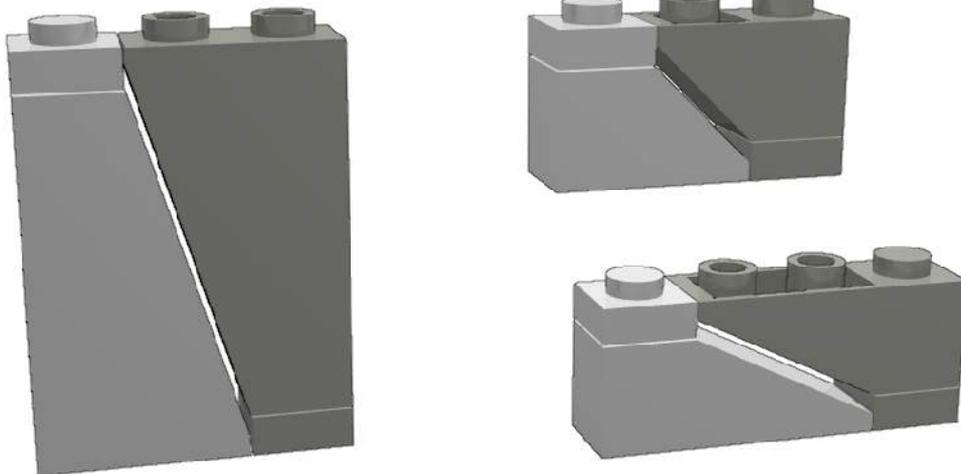
One plate height offsets

Half-stud offset

If the two slope bricks are placed side by side with a half-stud offset, the gaps are different.
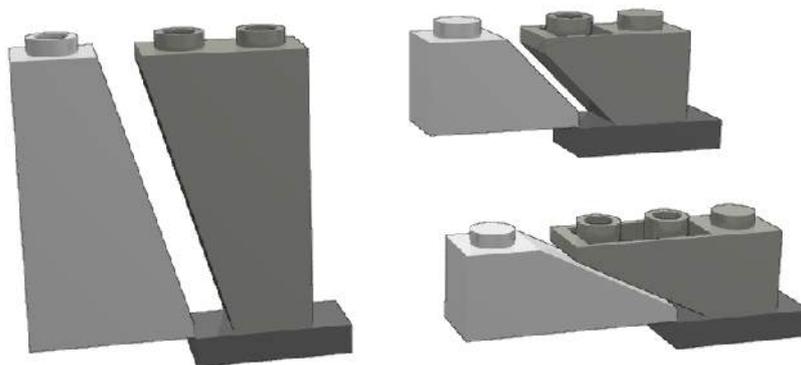
In the case of the 1x2x1 slopes the gap is higher,
in the case of the 1x3x1 slopes, the gap is reduced and negligible,
in the case of the 1x2x3 slopes the gap is higher but allows the placement of a 1x4 tile.

This technique first seen on the TGV locomotive by Xavier Viallefont has the main advantage of allowing three colours scheme and/or fine diagonal striping.
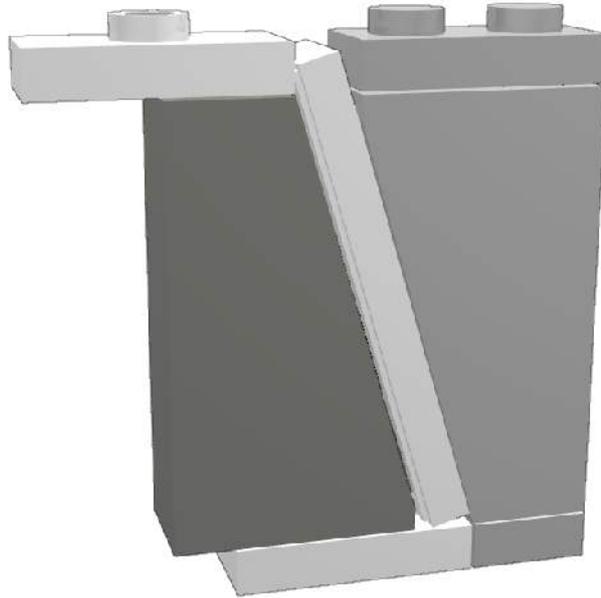

This technique has also been used to build Tudor style house decorative walls by Lenny Hoffman. The 1x4 tile is floating but you can use two 2x2 tiles and attached them in the back.
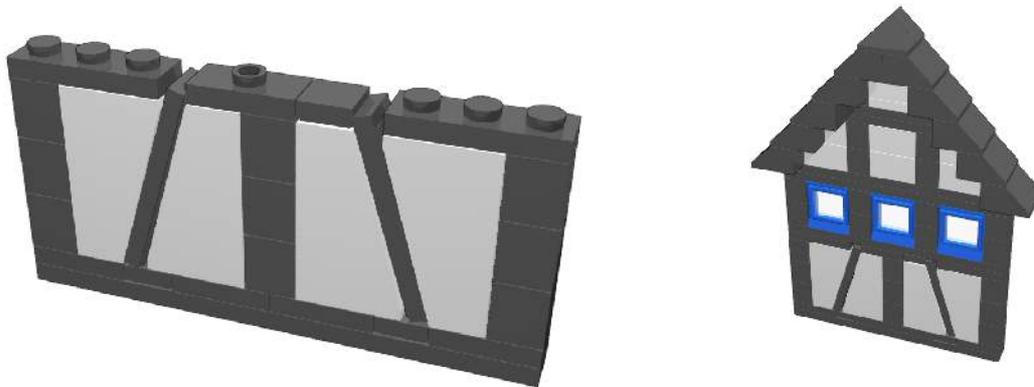
A similar technique, using the free space between parts to fill it with floating tiles, has been developed by James Brink to create five wide windows, again, in the Tudor style.
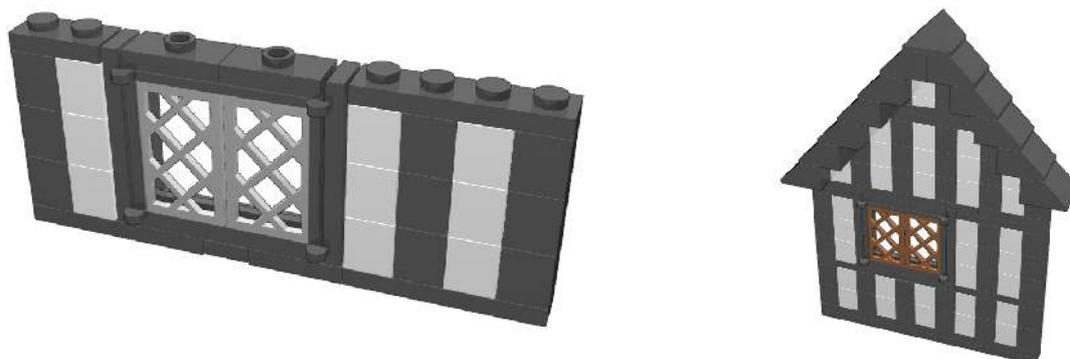
Chapter 5

Micro-striping

Micro-striping techniques allow to create stripe coloured shape with a width of less than the height of one plate, i.e. less than 8 LDU. Micro-striping is an original idea from Steve Barile on 2002 developed by James Mathis in the LEGO Trains theme.

The micro-striping is possible thanks to parts with thin component. Micro-striping then will often require SNOT or/and offset mounting. Thin parts are components of : flags, brick hinges top, brackets, fences, panels and baseplates. Most of them are 4 LDU thin. Brick hinges top are 2 LDU thin, the fences are 6 LDU.
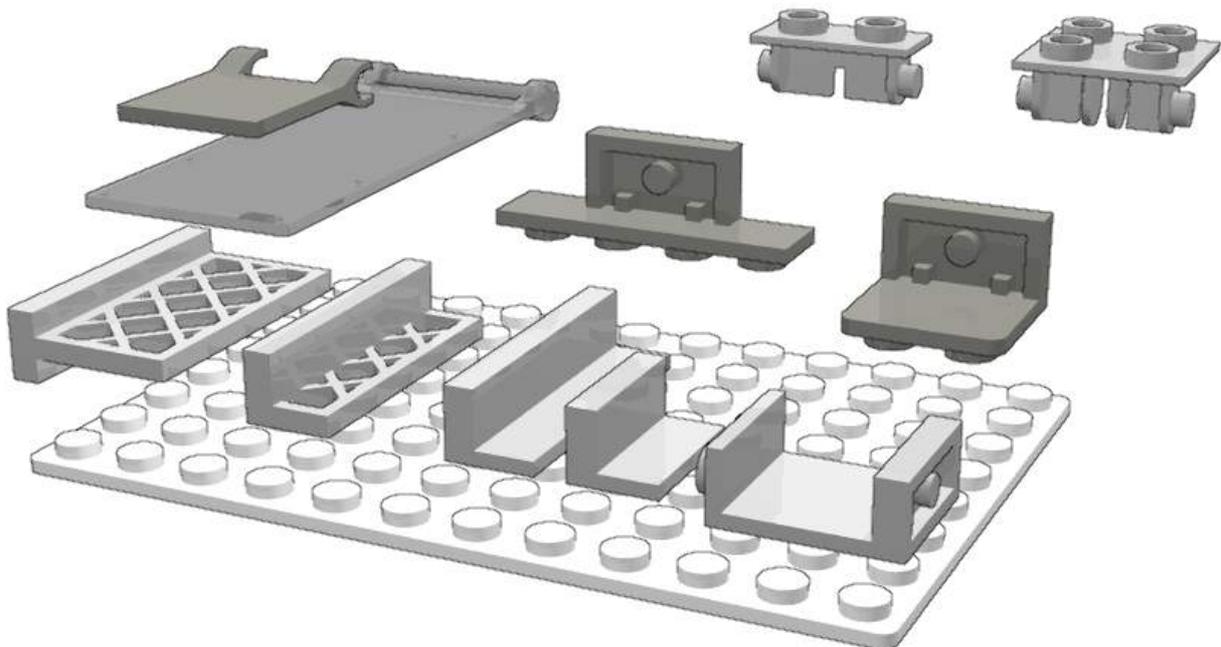
Thin parts

Micro-striping examples

Top hinges brick micro-striping : That's the simplest micro-striping technique, with no SNOT or offset building. Be careful that the lowest stripe is only 22 LDU high instead of 24.
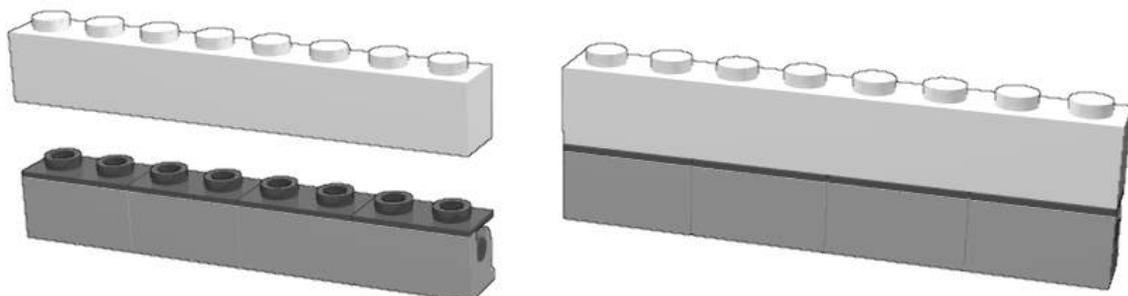
SNOT mounted 1x2-1x4 bracket micro-striping : This building requires SNOT, the lower stripe is 20 LDU high and there is a little front offset. This micro-striping building's length is at least a multiple of 4L.
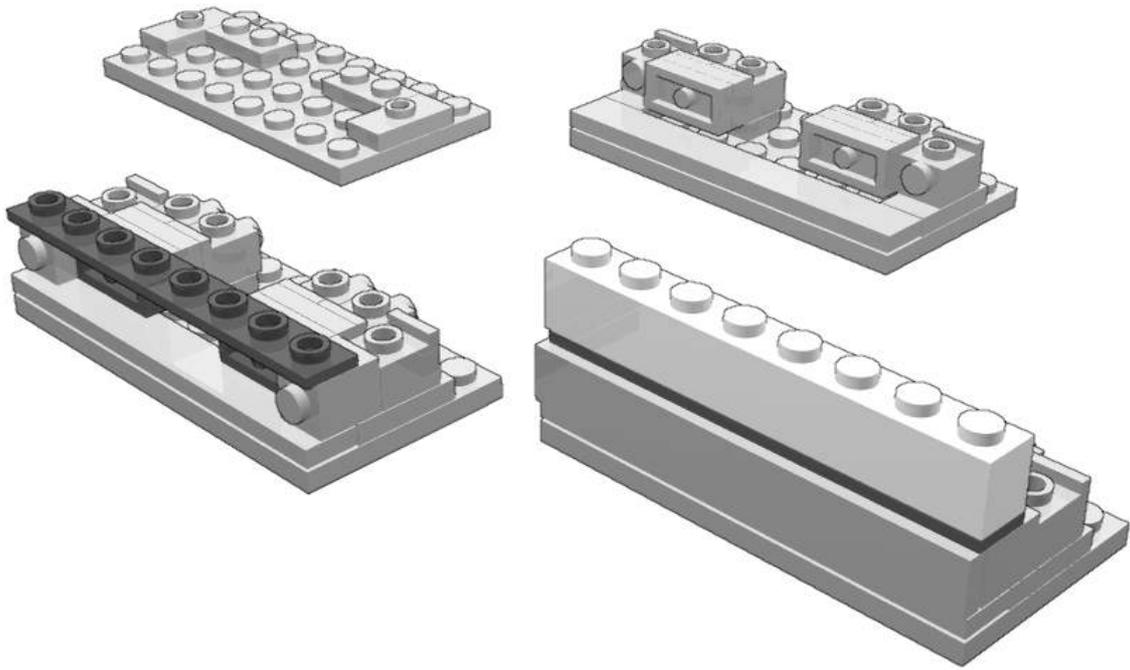
SNOT mounted 1x2-2x2 bracket micro-striping : This building is easier and his length is a multiple of 2. The lower stripe can be as low as 8 LDU but the total height present an offset of 4 LDU.
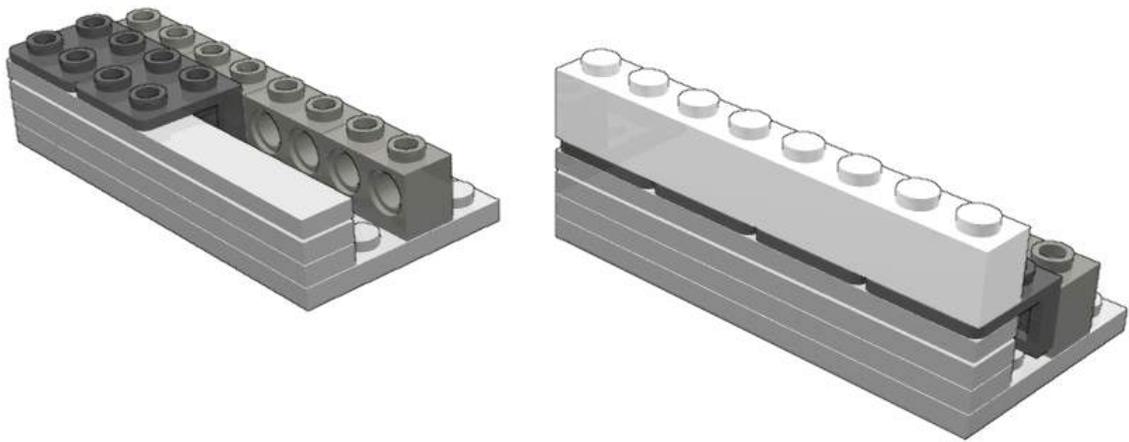
Chapter 6

Studs Not In a Row (SNIR)

Large parts – baseplates for instance - have regularly spaced studs on their top, shaping an orthogonal matrix. The space between the studs is 1L. Two 1x1 parts placed side by side on a base plate just leave a very small margin between them: the 1x1 parts placed side by side are prevent from being non-orthogonally placed. On SNIR techniques, parts are placed not simply side by side but in diagonal, to obtain a row not in the classical way.

SNIR 45

Assuming the dimension of 1x1 part and stud diameter, individual 1x1 part in this matrix can be non-orthogonally placed, in any angle as shown in the followings illustrations. Some figures :

- The distance between two studs is 1L,
- the gap between two studs is 0.4L,
- the diagonal dimension of a 1x1 part is 1.414L (square root of 2L).
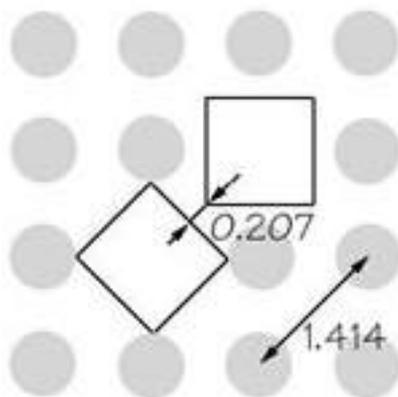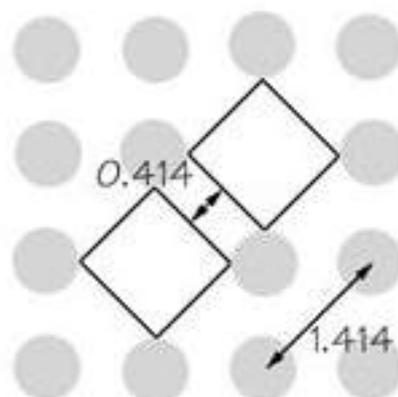
A   B

The B shape is a new and innovative Studs Not In a Row (SNIR) building technique. Some perfect vertically fitting and stud less upward side is possible using a 1x1 tile stacked on two 1x1 plates. The three plates (two plates and one stud less plate - tile) are 3x0.4=1.2L high. It equal the tile width (1L) added with a stud height (~0.2L).
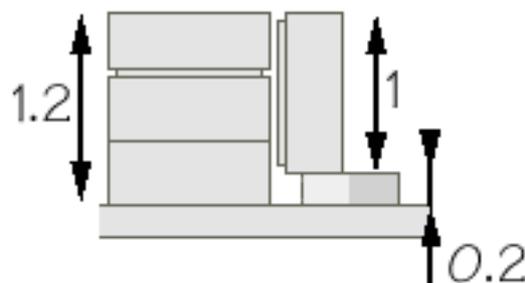
This technique has been originnally developped by Erik Amzallag.
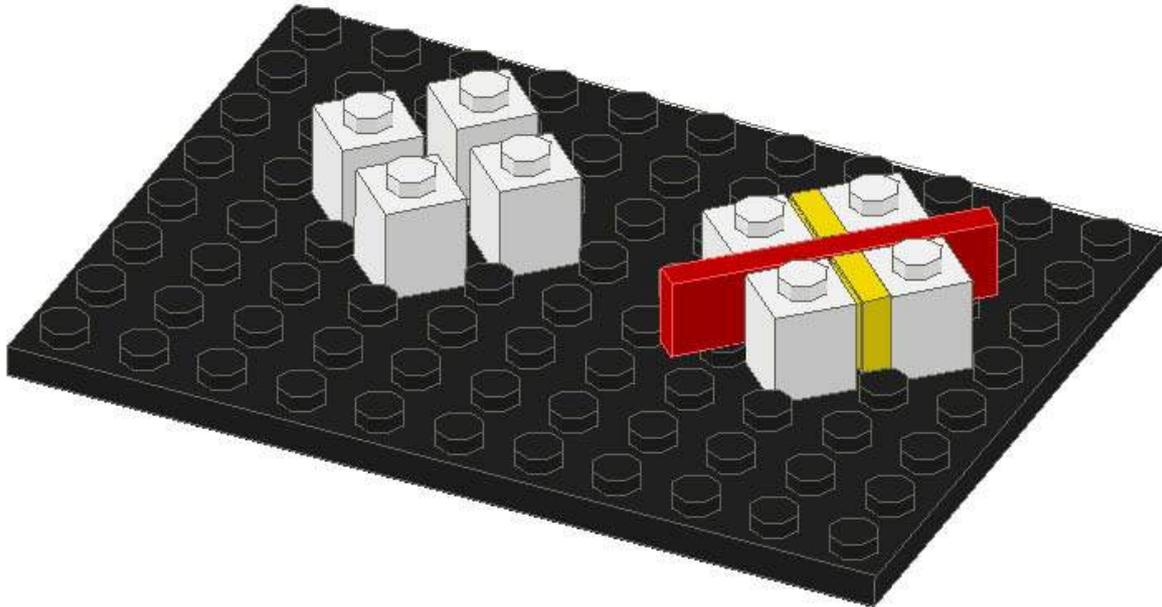
SNIR 27

This SNIR technique has been developped by Reinhard Beneke. It allows to build a wall at an angle of about 27° to the baseplate grid of studs. This angle is performed using jumper plate AZMEP technique. The 1x1 elements which the wall are made of (here bricks) may also be slightly turned to create of less regular shape.
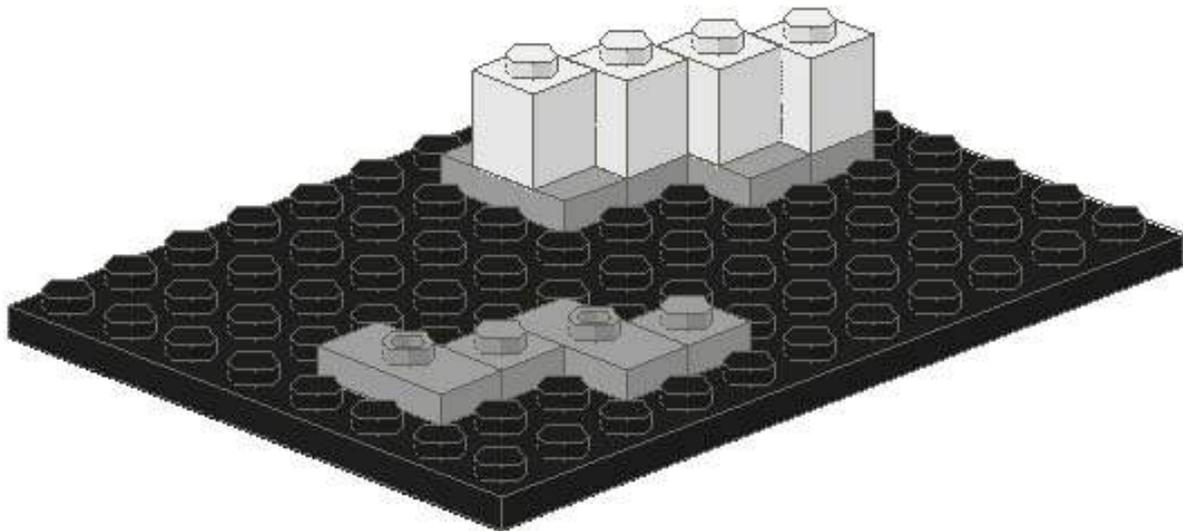
Chapter 7

Mixed cylinder curving

LEGO parts are not meant to be used to create nicely curved surfaces and you will obtain a pixelated looking. Of course you could use special purpose parts – rounded ones – but with limited choices : small diameter, colours restriction..

Larger smooth curved walls can be obtained, without stress, by mixing small regular parts (1x2 to 1x4) with 1x1 round parts (plates or bricks). Eric Brok has coined the "mixed cylinder curving" name to this building technique. This technique is very part consuming.

Thank to moulding tolerances, very big radius curved walls can be obtained by stressing a bit walls made of 1x2 parts.
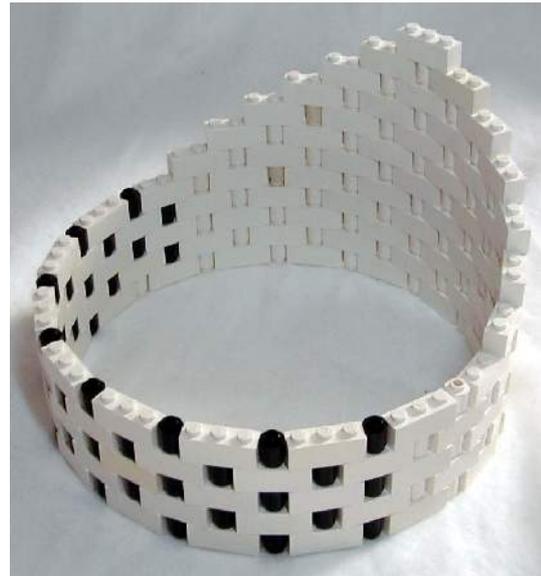
Credits

Vocabulary and geometry about LEGO plates and bricks

Tim Courtney, Steve Bliss, Ahui Herrera, Virtual LEGO
Various authors, BrickWiki, http://www.brickwiki.org/index.php/LDU
Zero Office Co., LTD., LEGO Technic Brick 1*4*1**,**
http://0937.zero-office.com/imgs/14-column/001/imgs/lego_modular.pdf

Chapter 1 - SNOT

Erik Amzallag, http://www.iltco.org/library/docs/TOPLESS_BM2004.pdf
James Mathis,Train SNOT, ILTCO library,
http://www.iltco.org/library/docs/Train_SNOT_JMathis_BW03.pdf
Holger Matthes, SNOT & Co, personal website**,**
http://www.holgermatthes.de/bricks_us/index.htm?http://www.holgermatthes.de/bricks_us/snot.htm
Jason Railton, Advanced SNOT, The Brick Issue #4, Christmas 2003,
http://www.brickish.org/bi/bi4.PDF
Jason Railton, LEGO SNOT, Brick Issue #3,Summer 2003**,** http://www.brickish.org/bi/bi3.pdf
Kim Toll, BrickMath, ILTCO library**,** http://www.iltco.org/library/docs/Brick%20Math.pdf

Chapter 2 – Offseting

Reinhard "Ben" Beneke, BrickShelf gallery, LEGO Trains in perfect size,
http://www.brickshelf.com/cgi-bin/gallery.cgi?f=74539

Chapter 3 - Letterings

Eric Harshbarger, http://www.ericharshbarger.org/lego/fonts.html

Chapter 4 – Diagonal striping

Lenny Hofmann, Advanced Tudor Style Instructions, Classic Castle,
http://www.classic-castle.com/howto/articles/AdvTudorHTML/html

Chapter 5 – Micro-striping

James Mathis, Lugnet train newsgroup, http://news.lugnet.com/trains/?n=17419
Various authors, BrickWiki, http://www.brickwiki.org/index.php/Micro_striping_techniques

Chapter 6 – Studs Not In a Row (SNIR)

Various authors, BrickWiki http://www.brickwiki.org/index.php?title=SNIR_techniques
Erik Amzallag, Lugnet post, A window using SNOT and SNIR techniques ,
http://news.lugnet.com/annouce/?n=2692
Reinhard Beneke, BrickShelf gallery, Old fishermans house near the shore,
http://www.brickshelf.com/cgi-bin/gallery.cgi?f=69760

Chapter 7 – Mixed cylinder curving*

Eric Brok, LEGO on my mind, http://www.ericbrok.com/legomind/projects/buildings/curvwall.htm

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