

Brick Geometry

Brickworld 2014

Chicago, Illinois

June 13, 2014

Bill Ward

bill@wards.net

www.brickpile.com



© 2008-2014 William R. Ward

Some Rights Reserved

License: <http://creativecommons.org/licenses/by-nc-sa/3.0/us/>

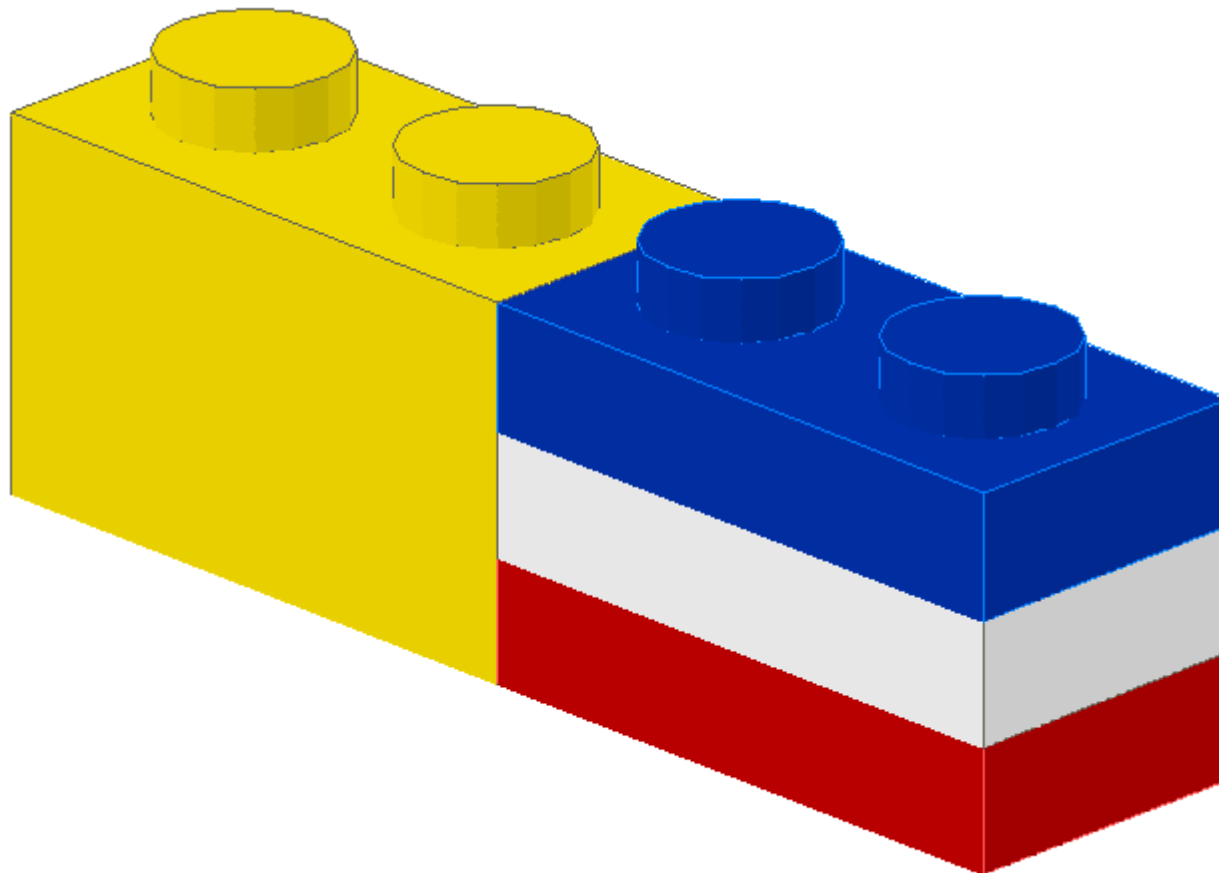


Ratios and Dimensions

Basic LEGO Geometry

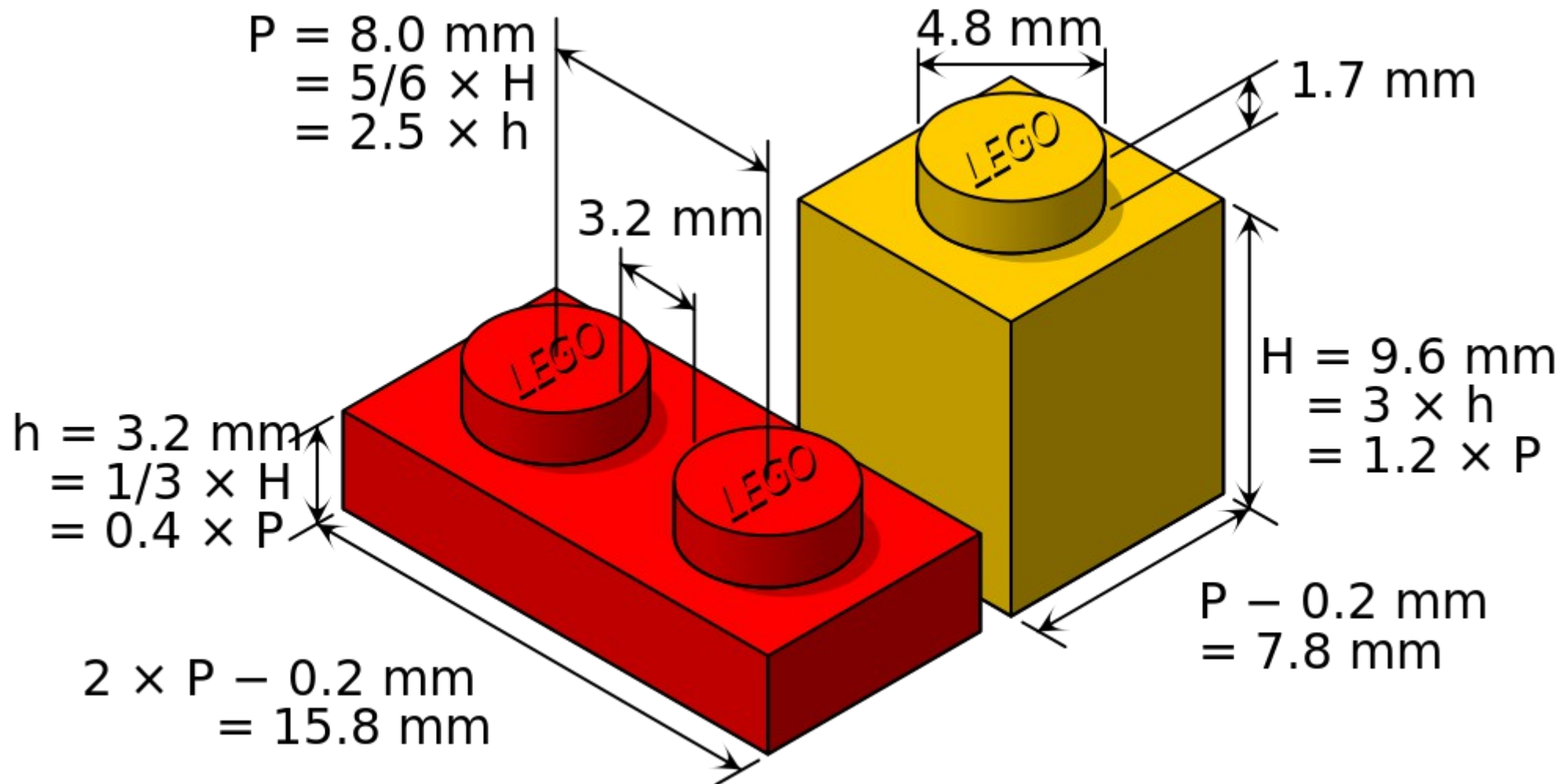
1 brick = 3 plates

Everyone knows this, I hope...



LEGO Dimensions

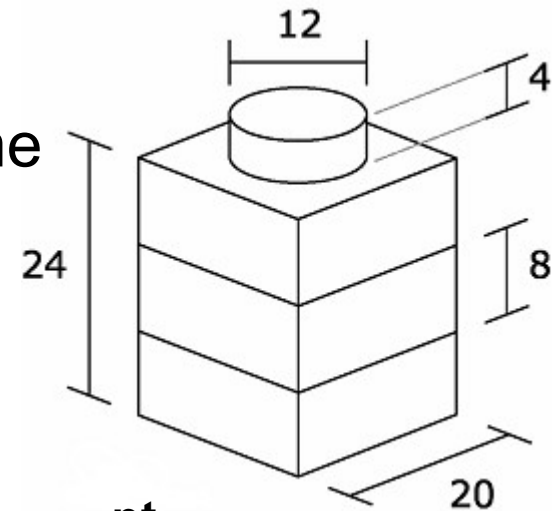
Quick! Memorize all these numbers. There will be a quiz later.



Math is Hard!

LDU = LDraw Unit

- A 1x1 stud brick or plate is $\frac{5}{16}$ " or 8mm (0.8cm)
- The height is $\frac{6}{16}$ " or 9.6mm (0.96cm)
- To make the math easier, LDraw designers came up with the LDraw Unit (LDU)
- Everything is a nice, easy integer this way!



	<u>LDU</u>	<u>studs</u>	<u>bricks</u>	<u>plates</u>	<u>cm</u>	<u>inch</u>	<u>pt</u>
LDU	1	1/20	1/24	1/8	0.04	1/64	9/8
studs	20	1	5/6	5/2	0.8	5/16	45/2
bricks	24	6/5	1	3	0.96	6/16	27
plates	8	2/5	1/3	1	0.32	2/16	9
cm	25	1.25	1.04	3.125	1	0.39	28.3
inch	64	3.2	8/3	8	2.54	1	72
pt	8/9	2/45	1/27	1/9	0.0353	1/72	1

LEGO Bricks Are Not Square

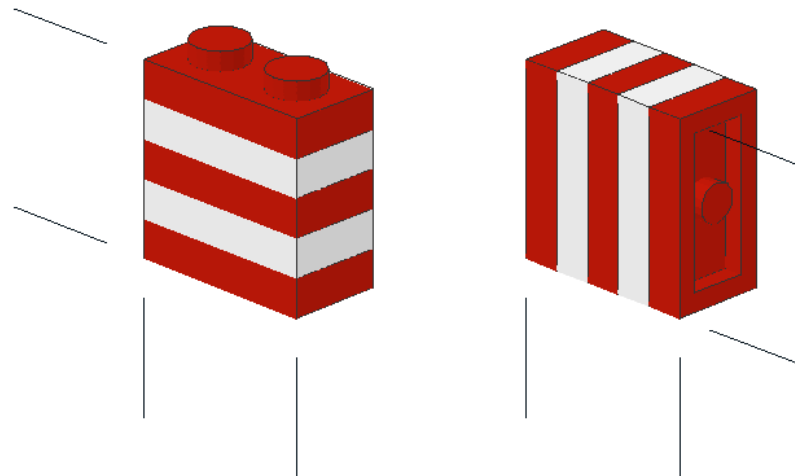
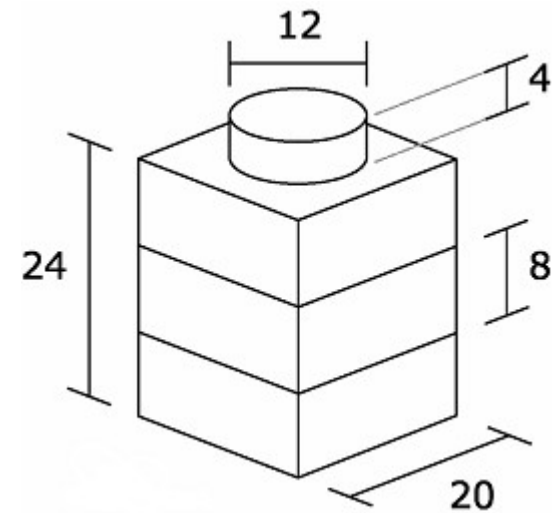
Bricks are 8mm wide by 9.6mm high

How do you make widths and heights match?

LDU makes the math easy....

How many plates = how many studs?

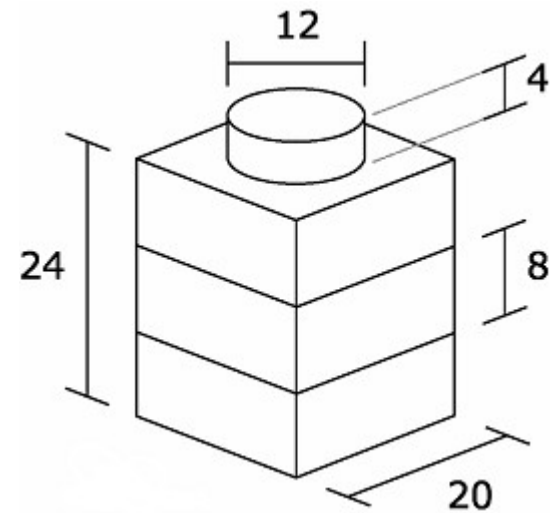
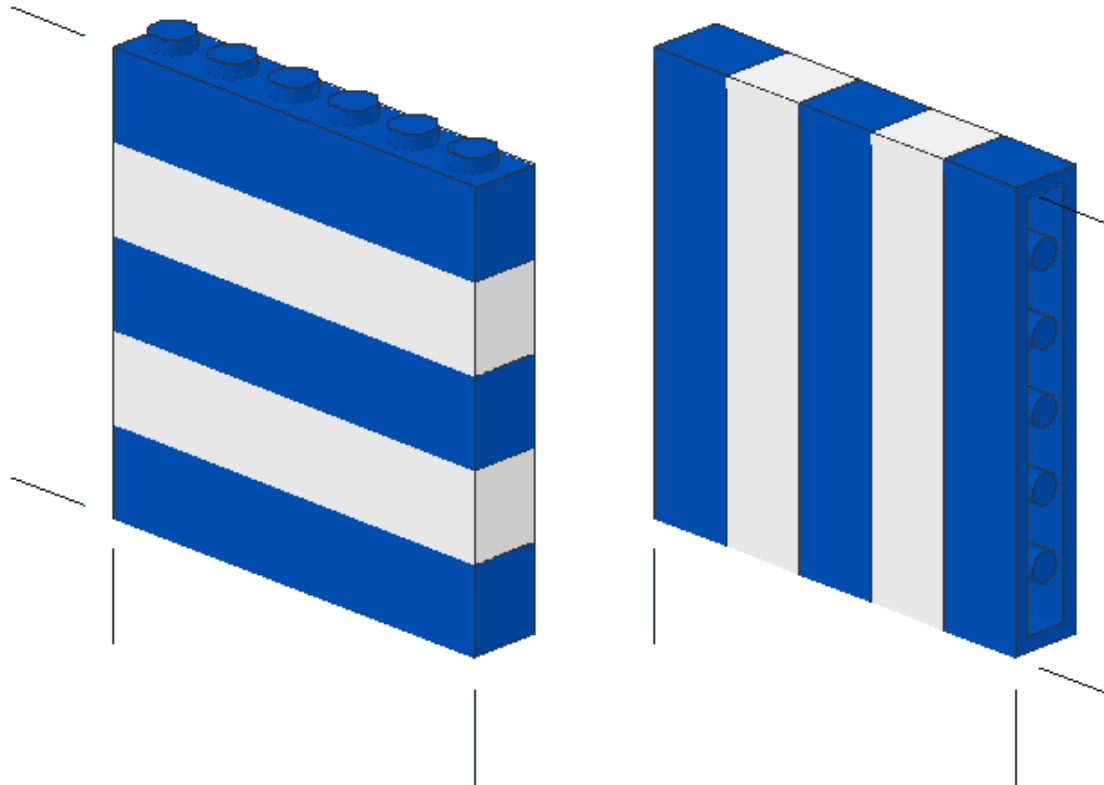
- 2 studs = $2 \times 20 = 40$ LDU
- 5 plates = $5 \times 8 = 40$ LDU



6:5 Brick Ratio

How many bricks = how many studs?

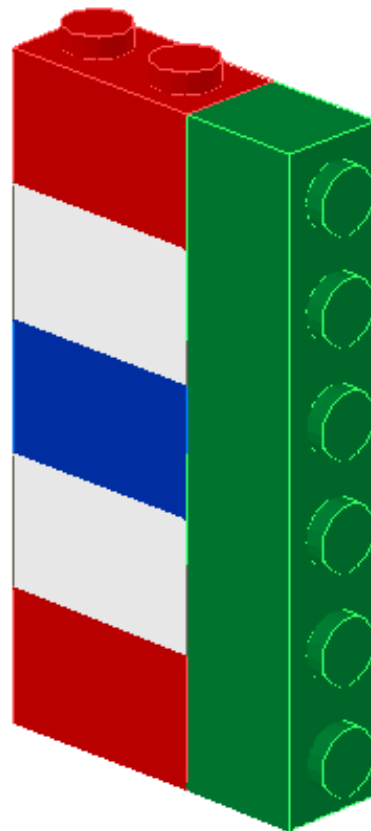
- 6 studs = $6 \times 20 = 120$ LDU
- 5 bricks = $5 \times 24 = 120$ LDU



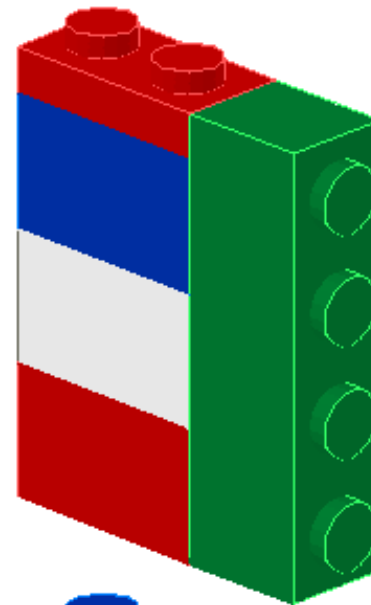
Even Numbers of Studs

Any even number of studs corresponds to a combination of bricks and plates, since $2 \text{ studs} = 5 \text{ plates}$

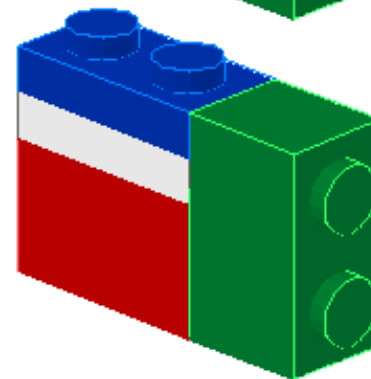
6 studs =
5 bricks =
120 LDU
(or 15 plates)



4 studs =
 $3 \frac{1}{3}$ bricks =
80 LDU
(or 10 plates)

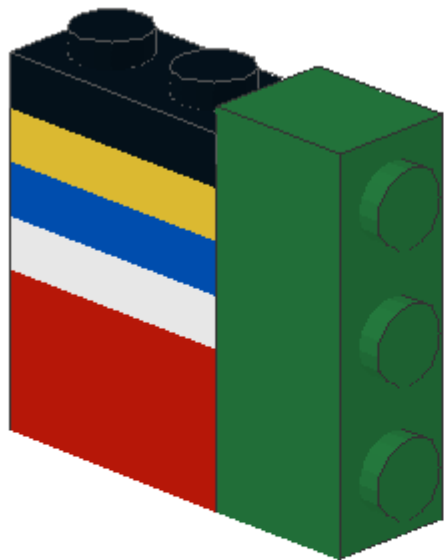


2 studs =
 $1 \frac{2}{3}$ bricks =
40 LDU
(or 5 plates)



Odd Numbers of Studs

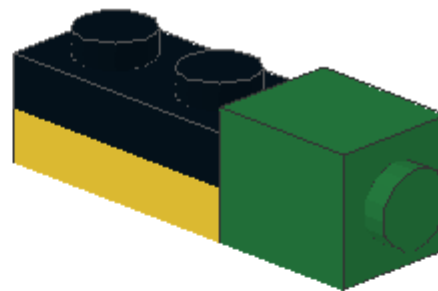
Since 1 stud = $2\frac{1}{2}$ plates, no combination of plates adds up to exactly one stud



3 studs = 60 LDU

1 brick + 4 plates = 56 LDU

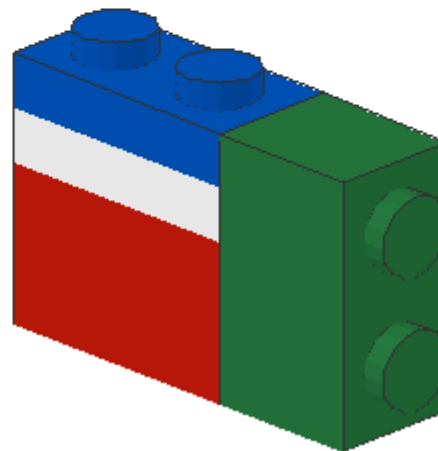
?? = 4 LDU
(Missing $\frac{1}{2}$ plate!)



1 stud = 20 LDU

2 plates = 16 LDU

?? = 4 LDU
(Missing $\frac{1}{2}$ plate!)



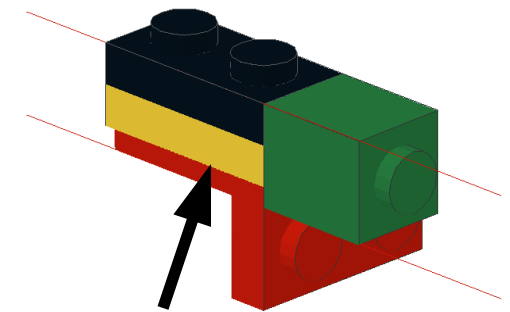
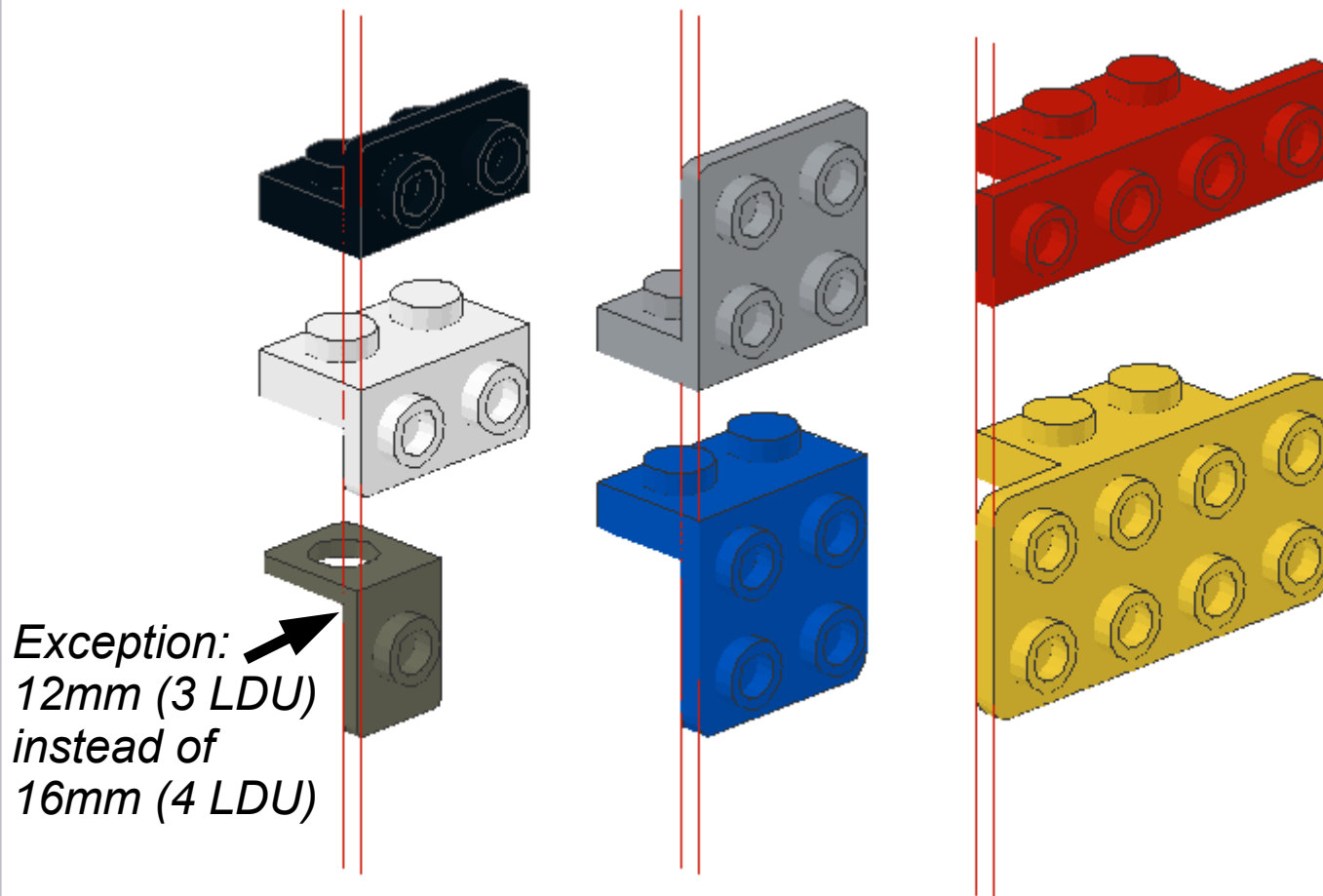
2 studs = 40 LDU

5 plates = 40 LDU

(OK)

But where do you get ½ plate?

One answer: brackets. The thin vertical plate is ½ the thickness of a normal plate, or 4 LDU



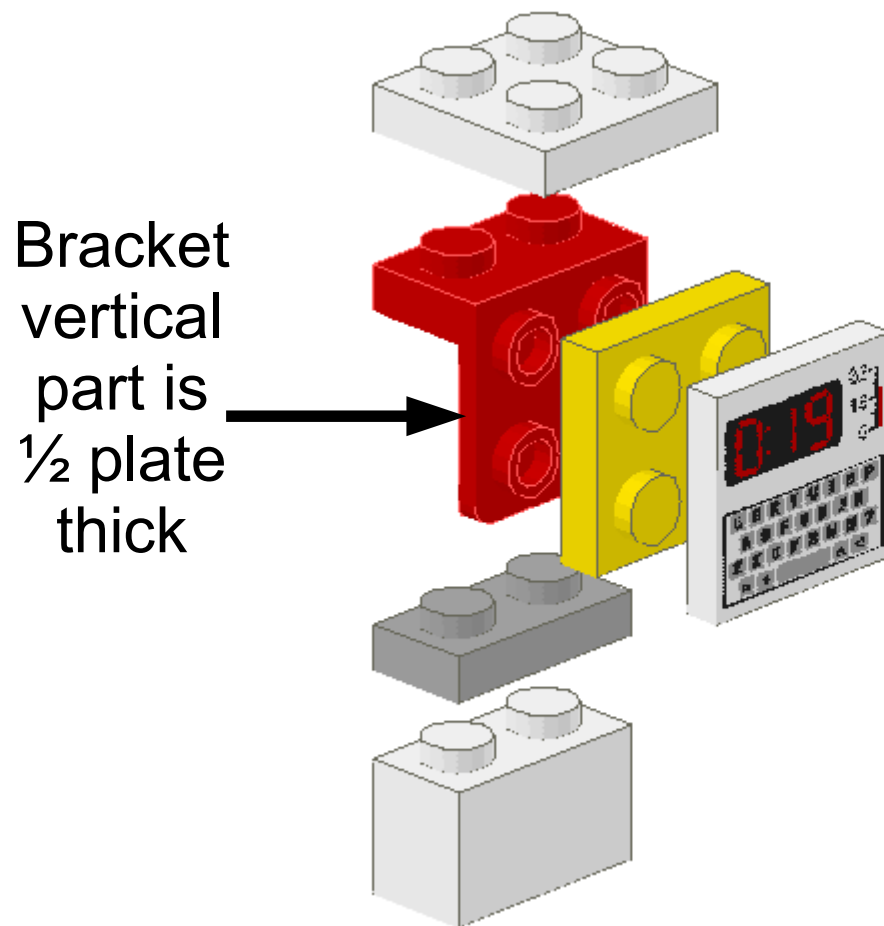
1 plate = 8 LDU thick
1 stud brick = 20 LDU
2 plates + bracket =
 $8 * 2 + 4 =$
20 LDU



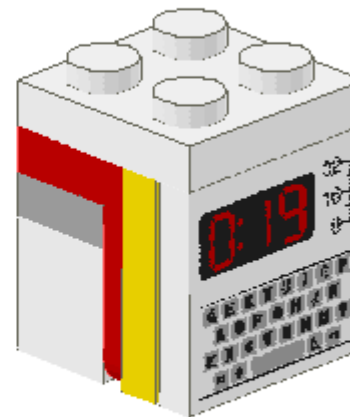
SNOT

Studs Not On Top

Using $\frac{1}{2}$ plate thickness from brackets



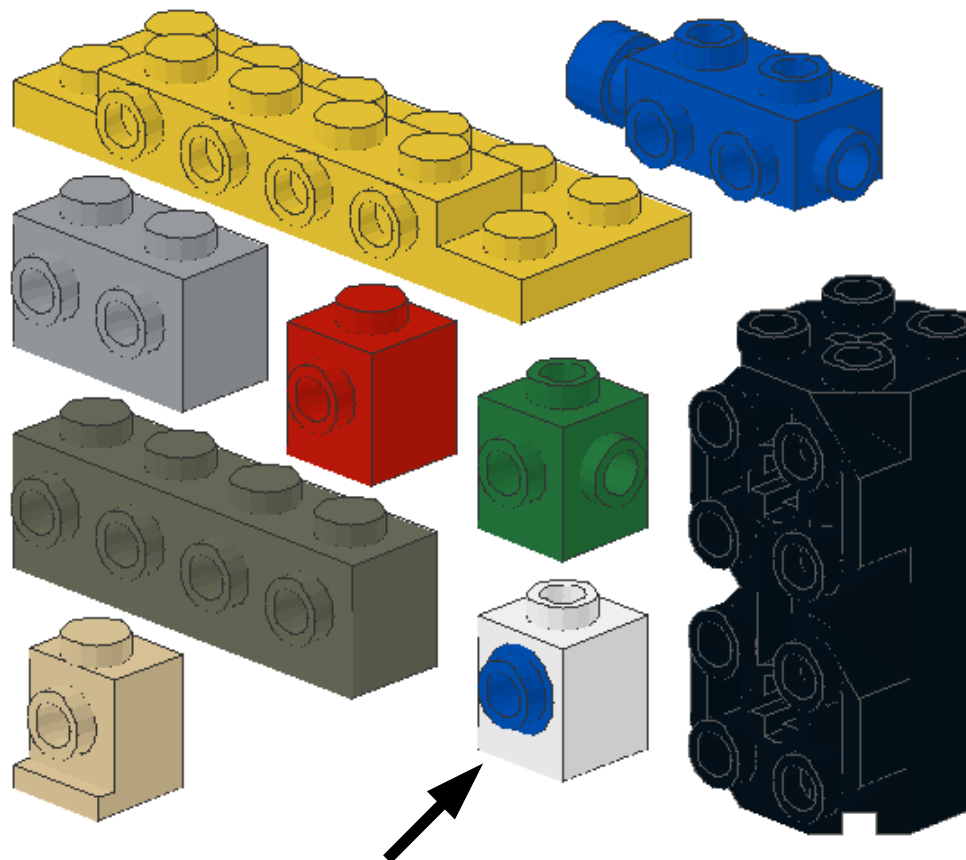
$\frac{1}{2}$ plate from bracket
+ 1 plate + 1 tile
= $2 \frac{1}{2}$ plates, same as 1 stud



Computer tile is
flush with edge
of white 2x2
plate.

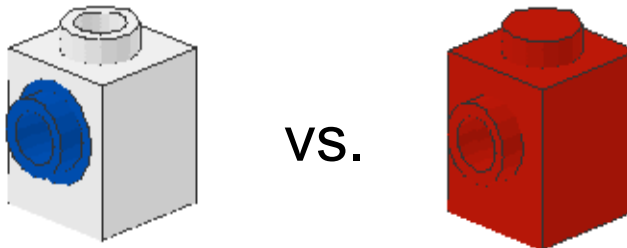
Bricks with Studs on the Side

LEGO has plenty of parts that have studs on the side, useful for SNOT (Studs Not On Top) design, similar to the brackets.



** Technic brick with $\frac{1}{2}$ pin is not quite the same – see next page*

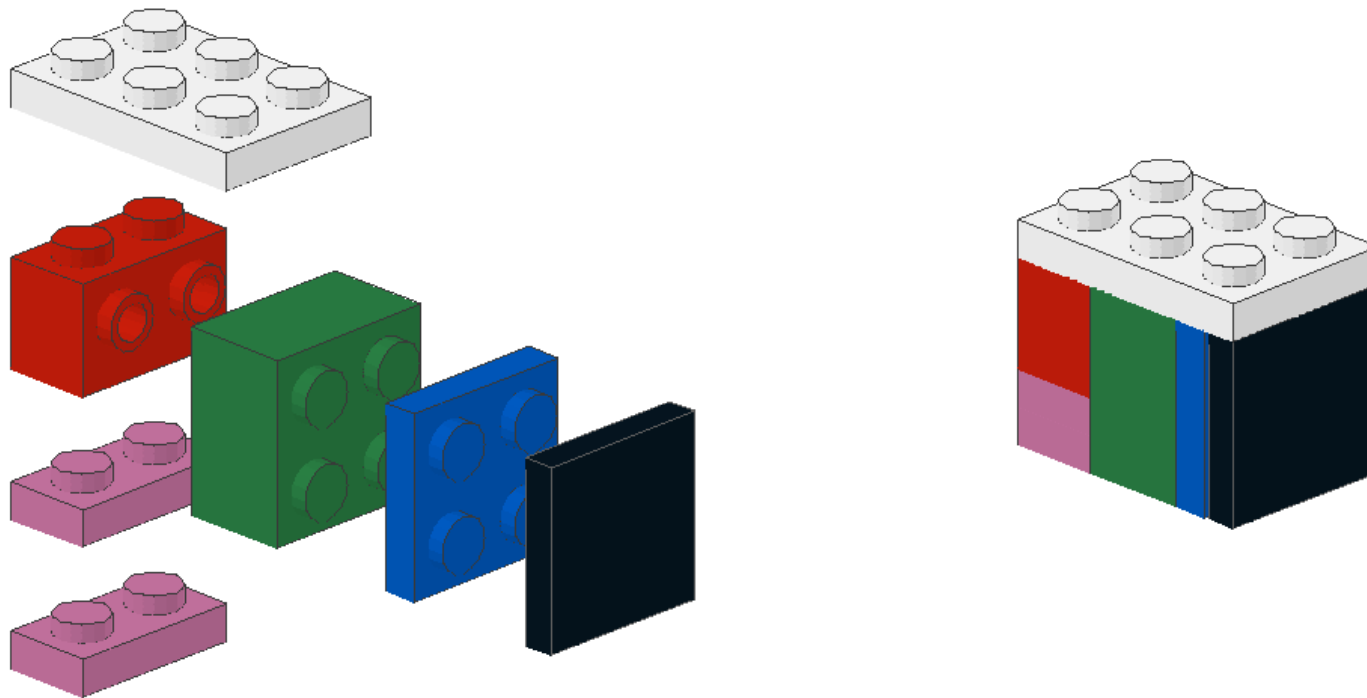
Caveat – Technic Pin Alignment



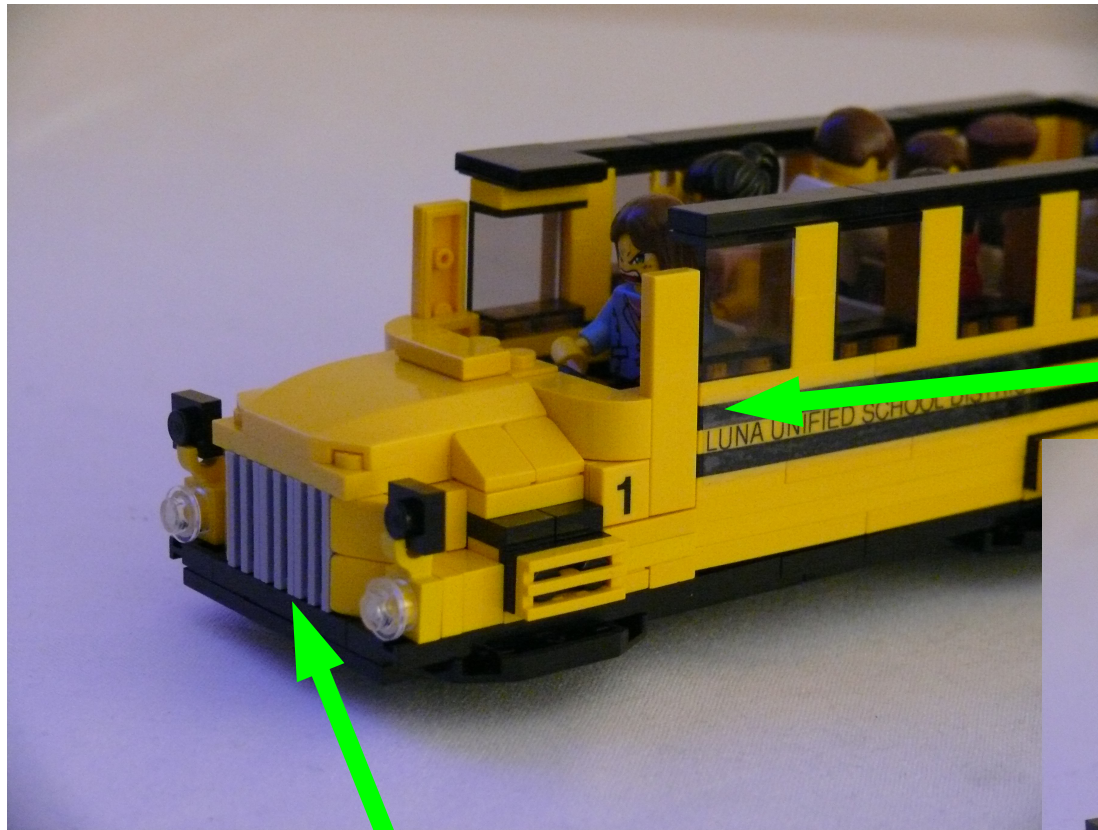
- *Technic pin hole placement is just a little higher (about 0.2mm) than stud-on-side placement.*
- *Some models may have alignment problems due to this.*
- *Reason: early Technic brick molds needed thicker plastic between pinhole and bottom of brick.*
- *Result: LEGO now produces more bricks with studs on side instead of using $\frac{1}{2}$ pins in Technic bricks – better for us anyway*

Bricks with studs on sides to mount flush

Use bricks with studs on sides to attach assemblies at 90 degrees.
To mount them flush, remember that 5 plates = 2 studs = 40 LDU.

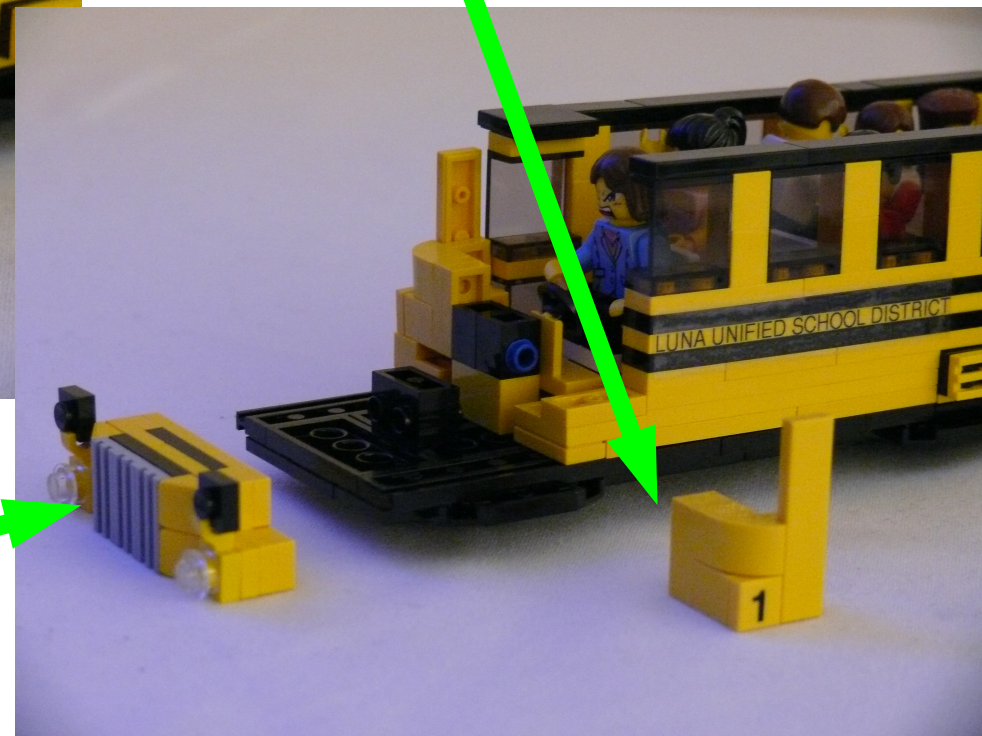


Flush tile examples

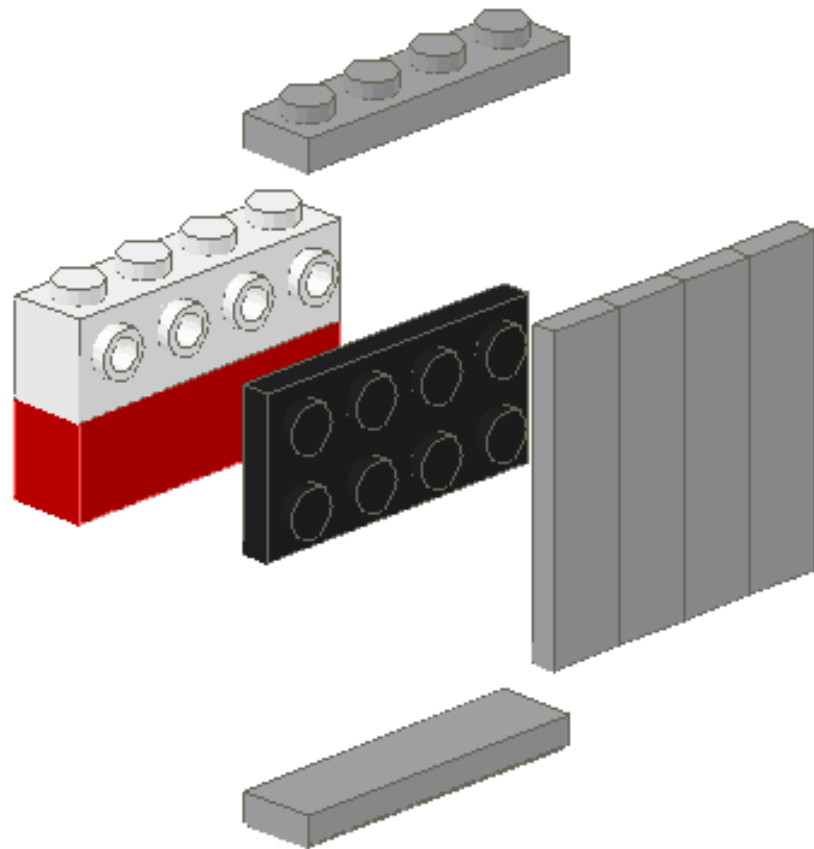


My School Bus model used
this technique in two places
Side panel

Grille and headlight assembly
Both are flush since 5 plates =
2 studs = 40 LDU

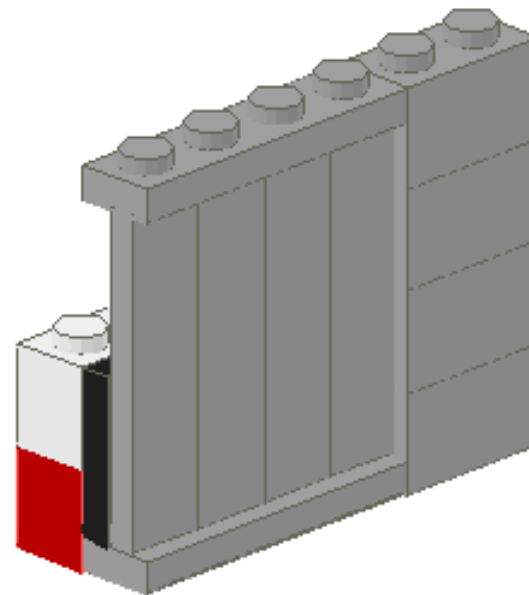


Inset Panels



1 plate + 2 studs (1 $\frac{2}{3}$ brick)
= 2 bricks

Use half-plate offsets to add texture to an otherwise flat wall



Tiles are $\frac{1}{2}$ plate inset

2 plates + 4 studs (3 $\frac{1}{3}$ bricks)
= 4 bricks

Inset panels example



Panels inset by $\frac{1}{2}$ plate

My F40PH Caltrain locomotive

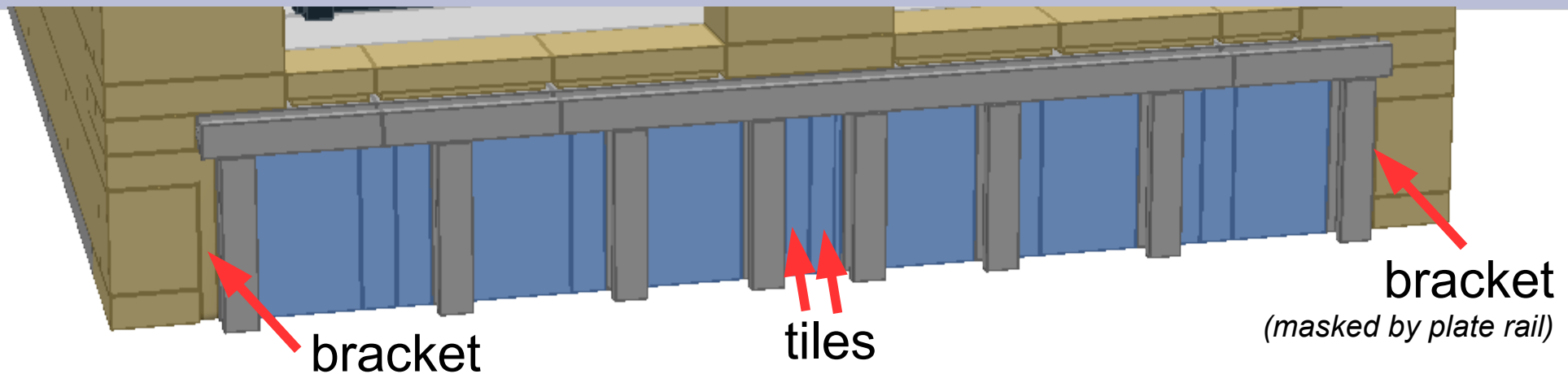
“De Vier Gekroonden”

This model by Vincent
“Mr. Tomato Bread”
Kessels uses some of
these techniques.

Photos used with permission



Sideways Building with Brackets



- Stack bricks and plates with a tile on the end
- Mount on bracket on each side facing inward
- $3 \text{ bricks} = 3 \times 24 = 72 \text{ LDU}$
 $7 \text{ plates} + 1 \text{ tile} = 8 \times 8 = 64 \text{ LDU}$
 $\text{bracket} = 4 \text{ LDU}$
 $\text{Total} = 140 \text{ LDU} = 7 \text{ studs}$
- Tiles on the ends press together and friction holds it all together

Model:
"De Vier Gekroonden"
by Vincent Kessels
a.k.a.
"Mr. Tomato Bread"

The Problem with Jumper Plates

- Requirement: 5-stud wide window openings with 6-stud wide arches above.
- Solution: offset the arches by $\frac{1}{2}$ stud using jumper plates
- Side effect: How to fill $\frac{1}{2}$ stud gap on ends?
- Imperfect solution: attach tile mounted sideways.
- $\frac{1}{2}$ stud = 10 LDU. Tile = 8 LDU. Gap of 2 LDU ($\frac{1}{4}$ plate) cannot be filled by any LEGO part. Any better ideas to fill a 10 LDU space?

Model:
"De Vier Gekroonden"
by Vincent Kessels
a.k.a.
"Mr. Tomato Bread"



Mosaic Dates on LEGO Modular Sets



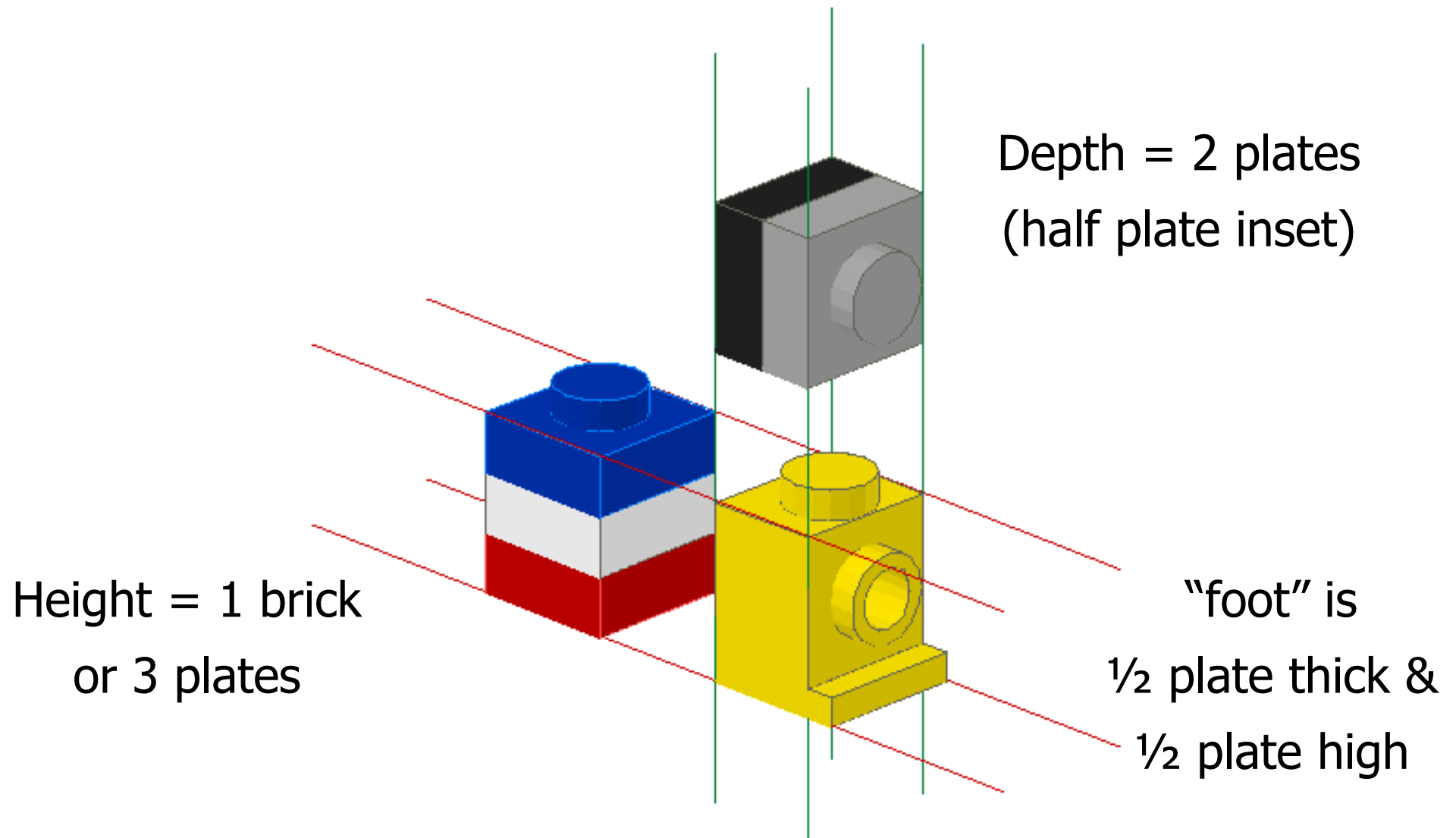
These sets (#10197 & 10224) use plates and tiles to create SNOT dates on the buildings.



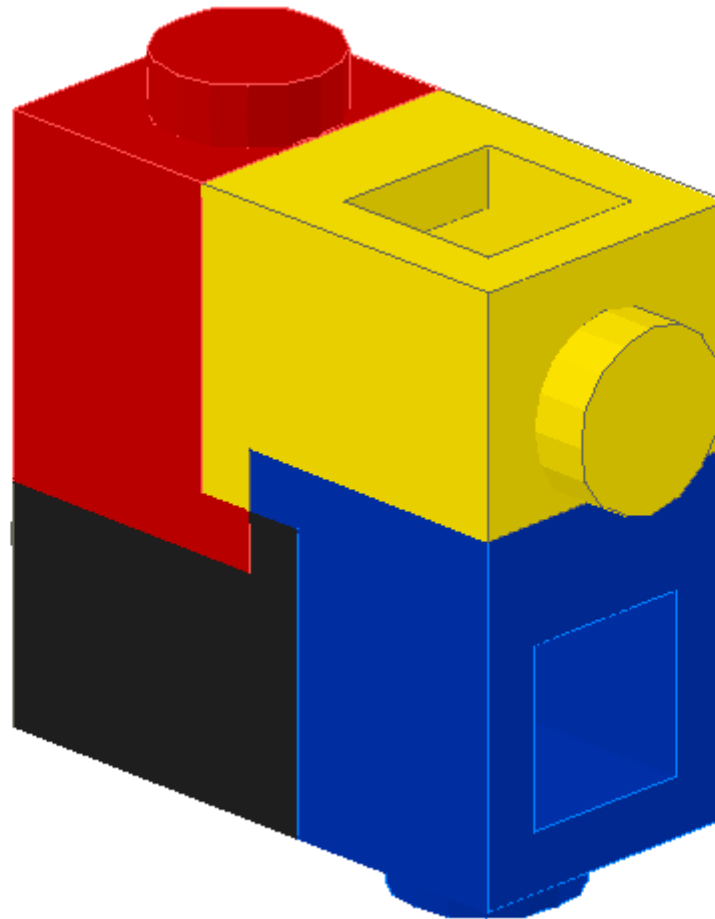


Fun with Headlight Bricks

Headlight Brick Dimensions



Four headlight bricks



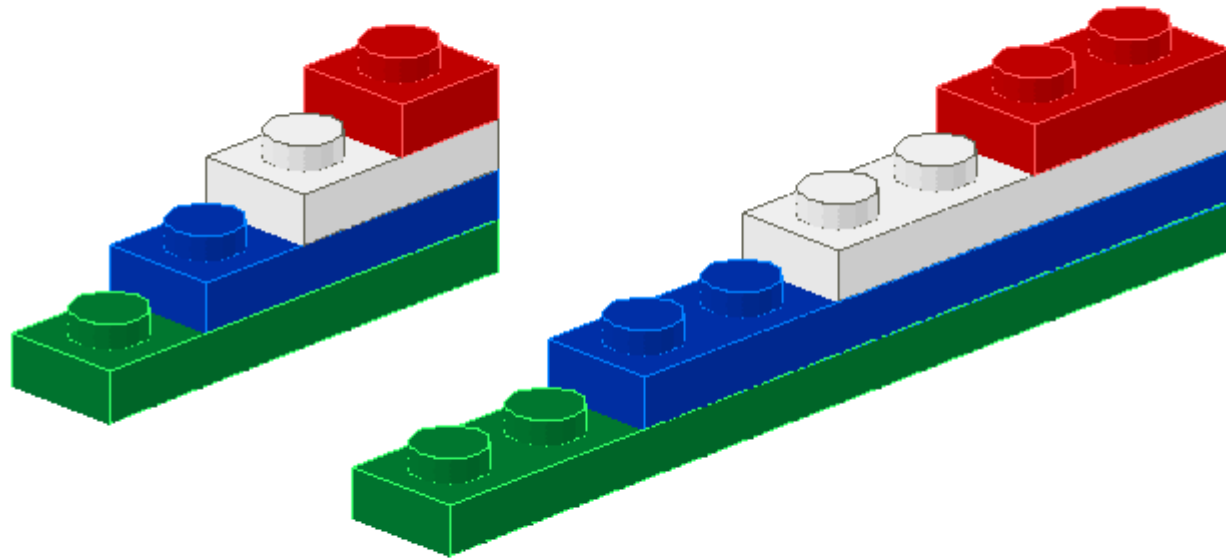
2 plates (red) +
3 plates (yellow) =
5 plates = 2 studs

Result: 5 plates or 2 studs in each of 4 directions.

Problem: Gradual Steps

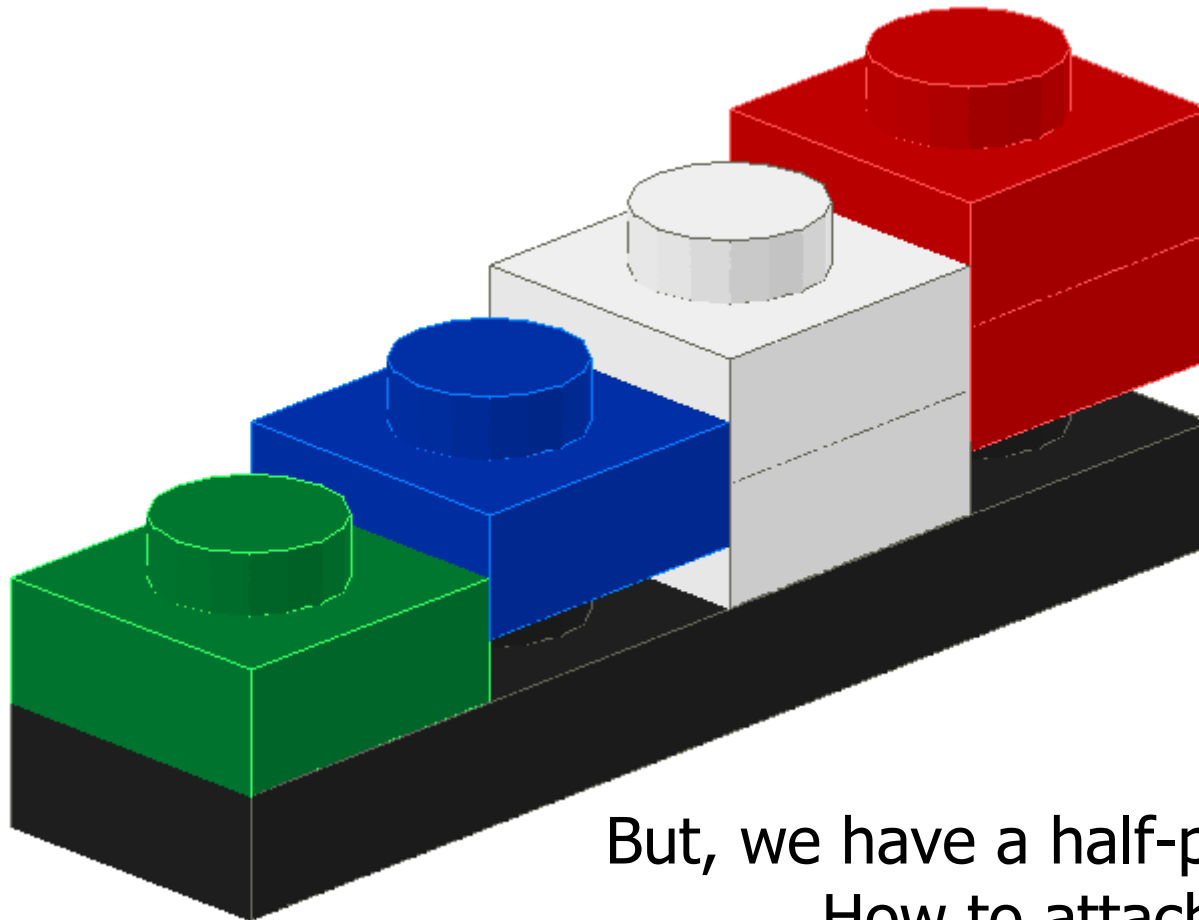
How do you make a gentle slope?

What if these are too steep?



Gradual Steps

For a more gradual slope, we'd like to mount every other one $\frac{1}{2}$ plate higher

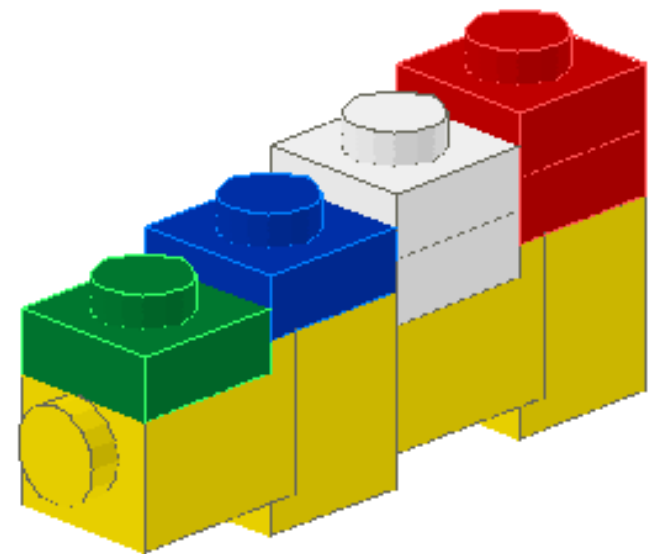
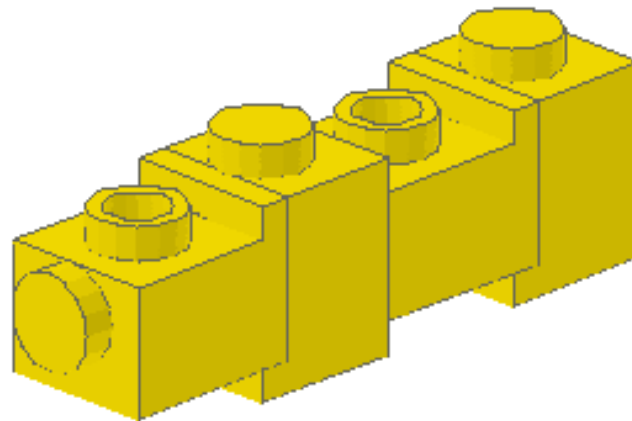


But, we have a half-plate hole to fill!
How to attach these?

Solution: Headlight Bricks

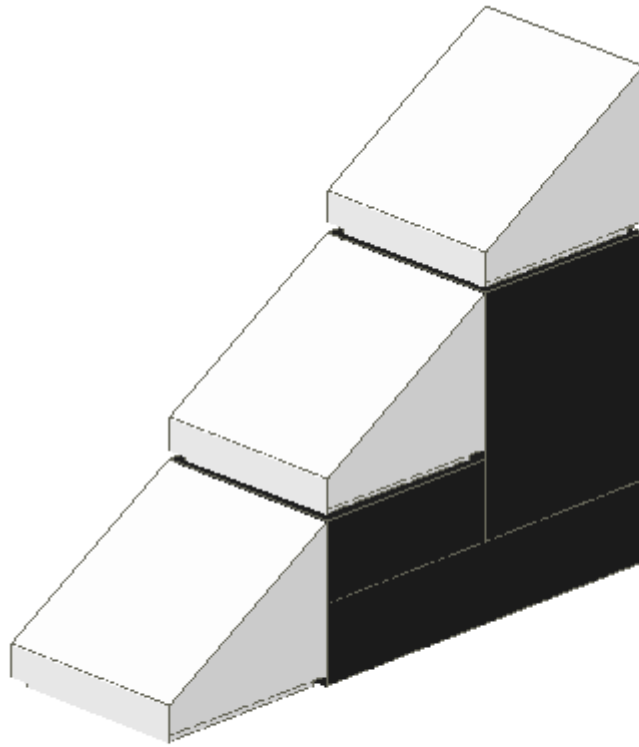
Alternate rotations for headlight bricks to take advantage of $\frac{1}{2}$ plate offset in "foot"

2 plates + $\frac{1}{2}$ plate = 1 stud



Half-plate lift from "foot"

Problem with “cheese slope”: Stairstep effect

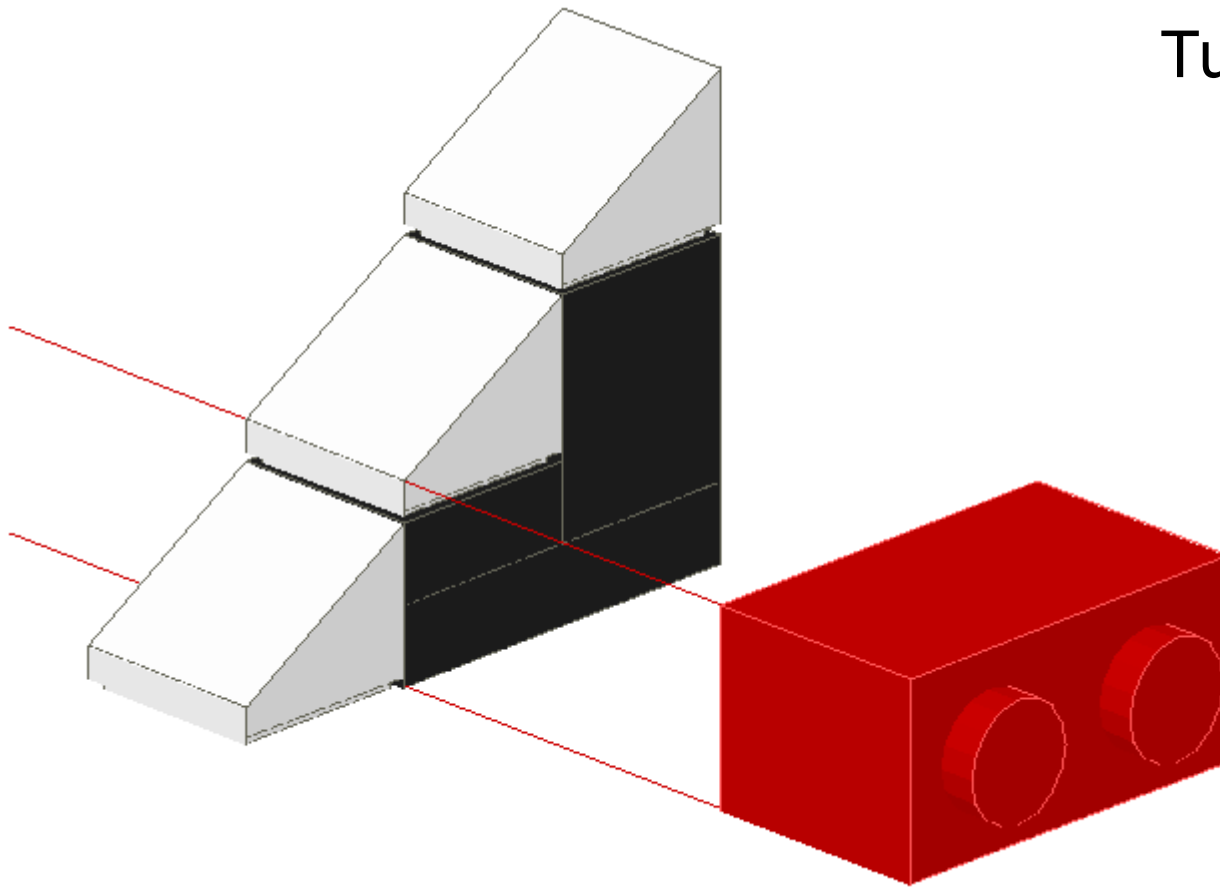


The 1x1 “cheese slope” is a very useful part but doesn't combine well with others of its kind to make a smooth slope.

This notch is needed for it to fit a stud inside, but is ugly.

Problem with “cheese slope”: Stairstep effect

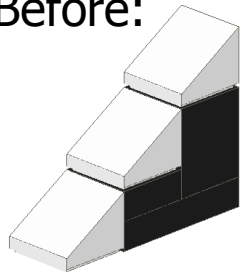
Turns out that “notch”
is $\frac{1}{2}$ plate thick.



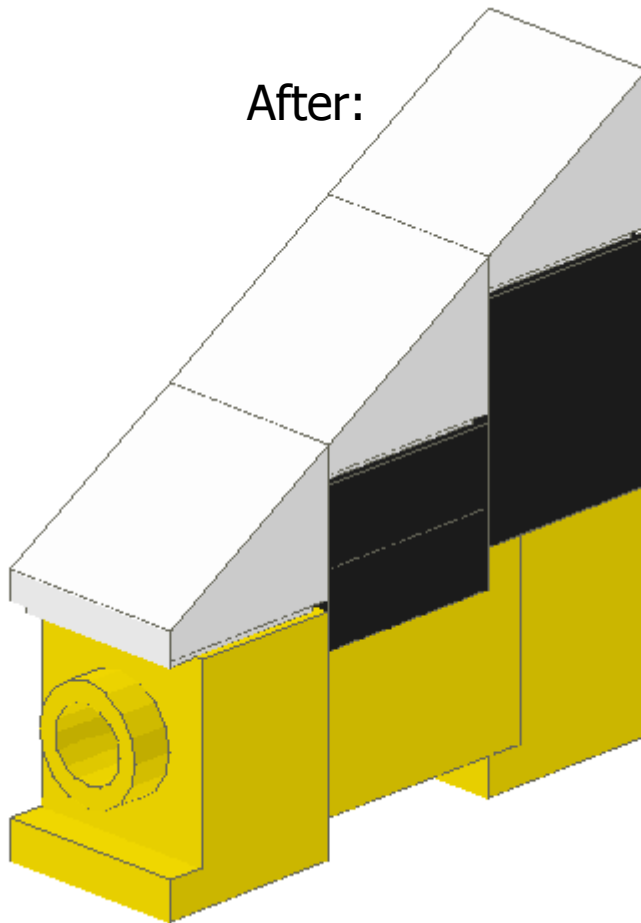
2 plates (height of cheese slope) + $\frac{1}{2}$ plate
= 1 stud

Solving the stairstep effect

Before:



After:

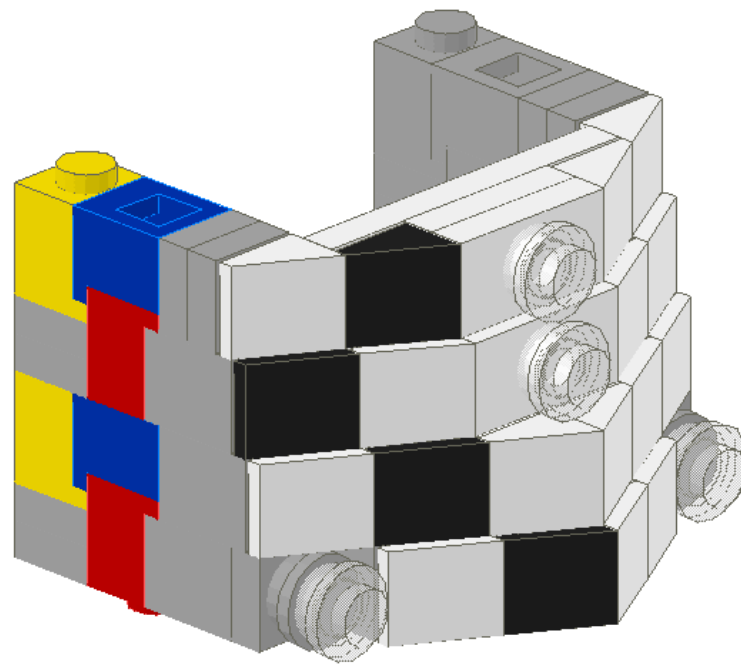
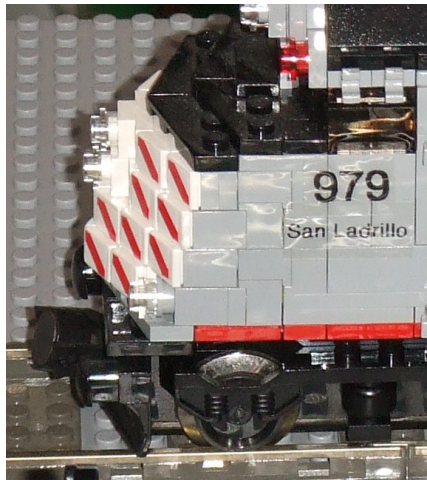


Used in Bram Lambrecht's
"Legoland Spacelines 979"
seen at BrickCon 2007

<http://www.flickr.com/photos/bram/1461137007/>
(used with permission)

Mount the center slope 1/2 plate lower for a smooth surface!

Useful for trains, too



My F40PH Caltrain locomotive

“Headlight Brick”

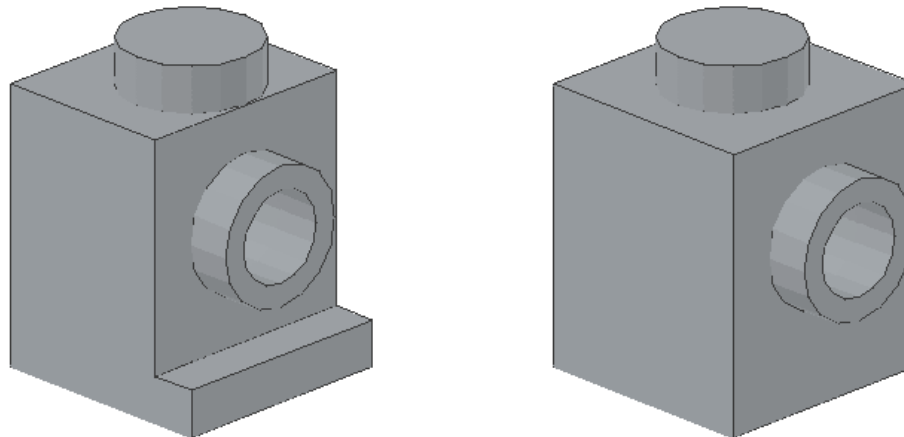
vs.

“Brick 1 x 1 with Stud on 1 Side”

Headlight Brick depth = 2 plates = 16 LDU

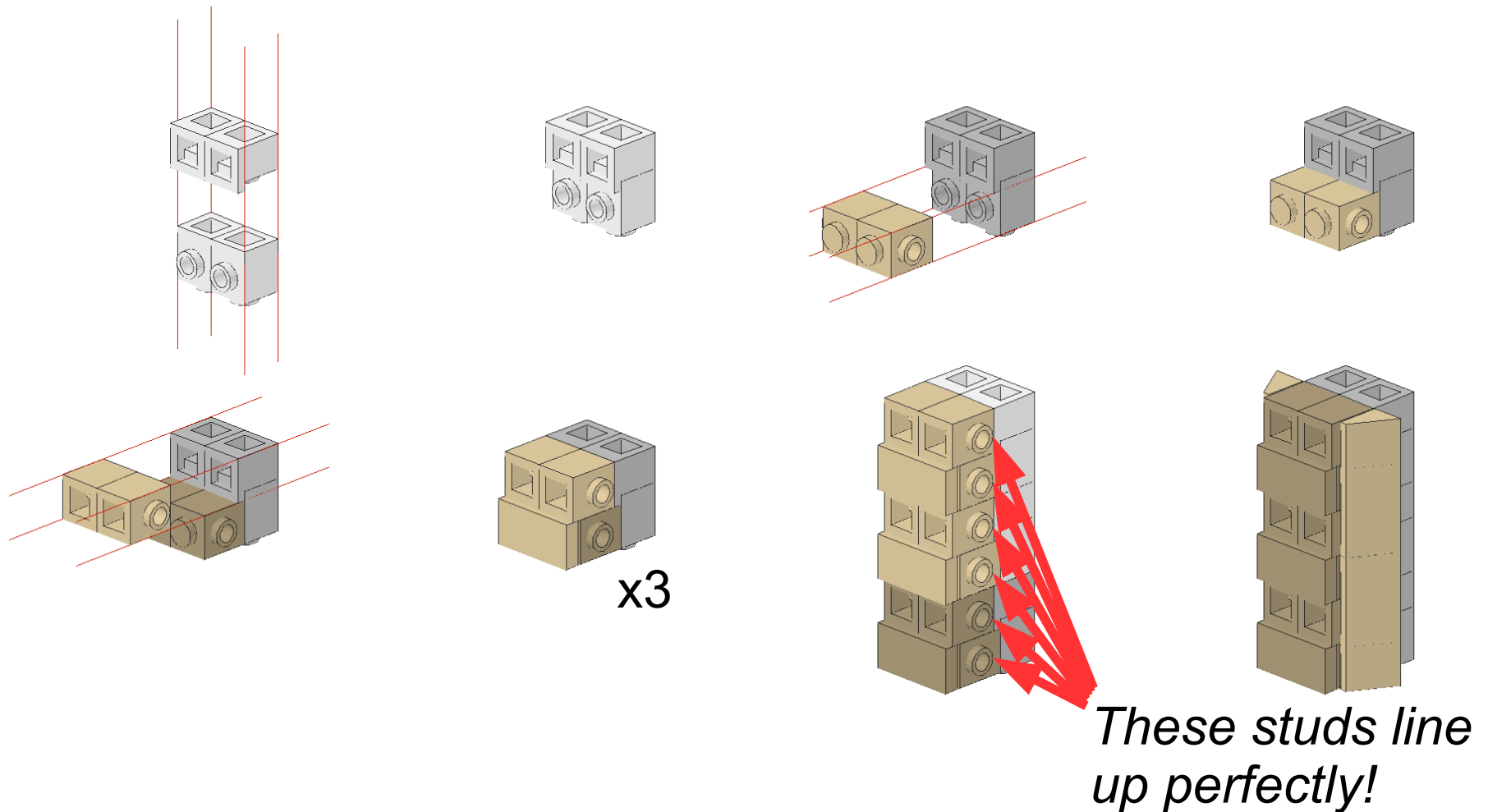
Brick depth = 2 ½ plates = 20 LDU

Combine these to achieve ½ plate differences in depth!



Hospital Bay Window example

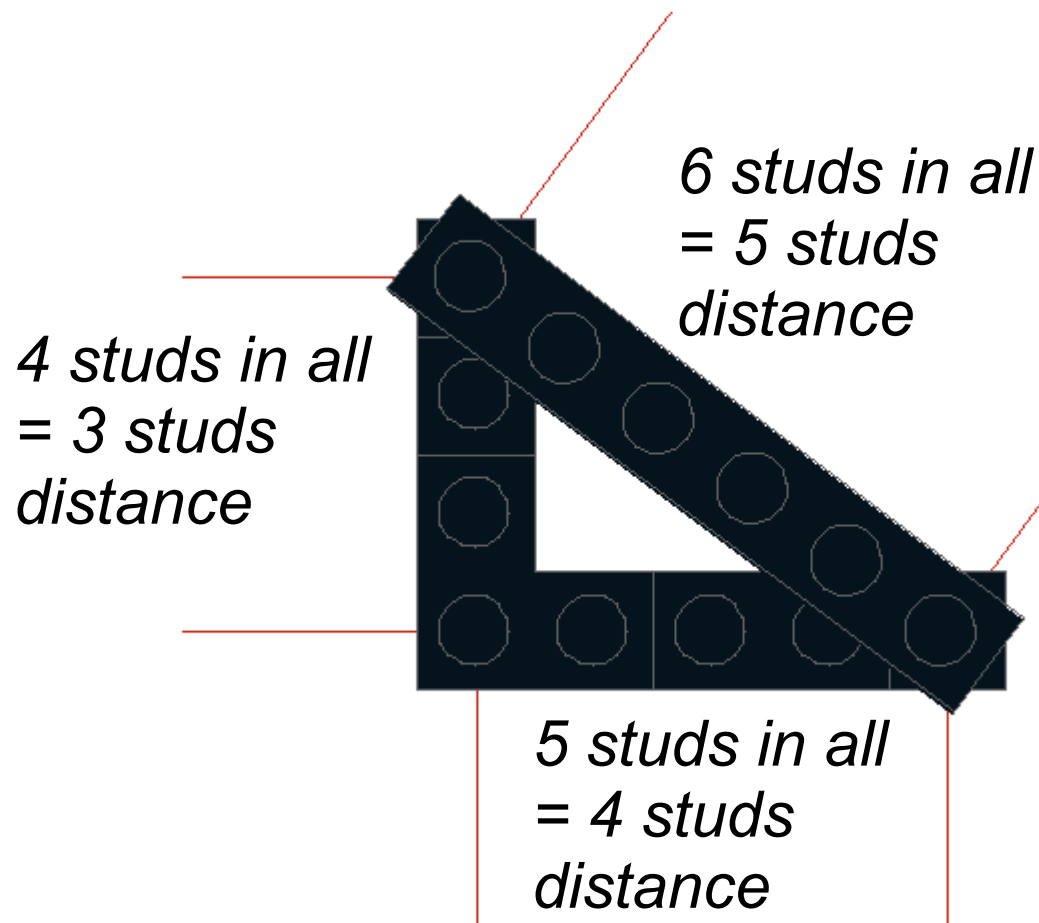
Windows (bottoms of bricks) are inset by $\frac{1}{2}$ plate





Triangles

Pythagorean Triples



Pythagorean Triples are right triangles where the sides are all integers. The 3-4-5 triangle is easy to make in LEGO.

Trick is, count between the *centers* of the studs! Each side is one stud longer than you might expect.

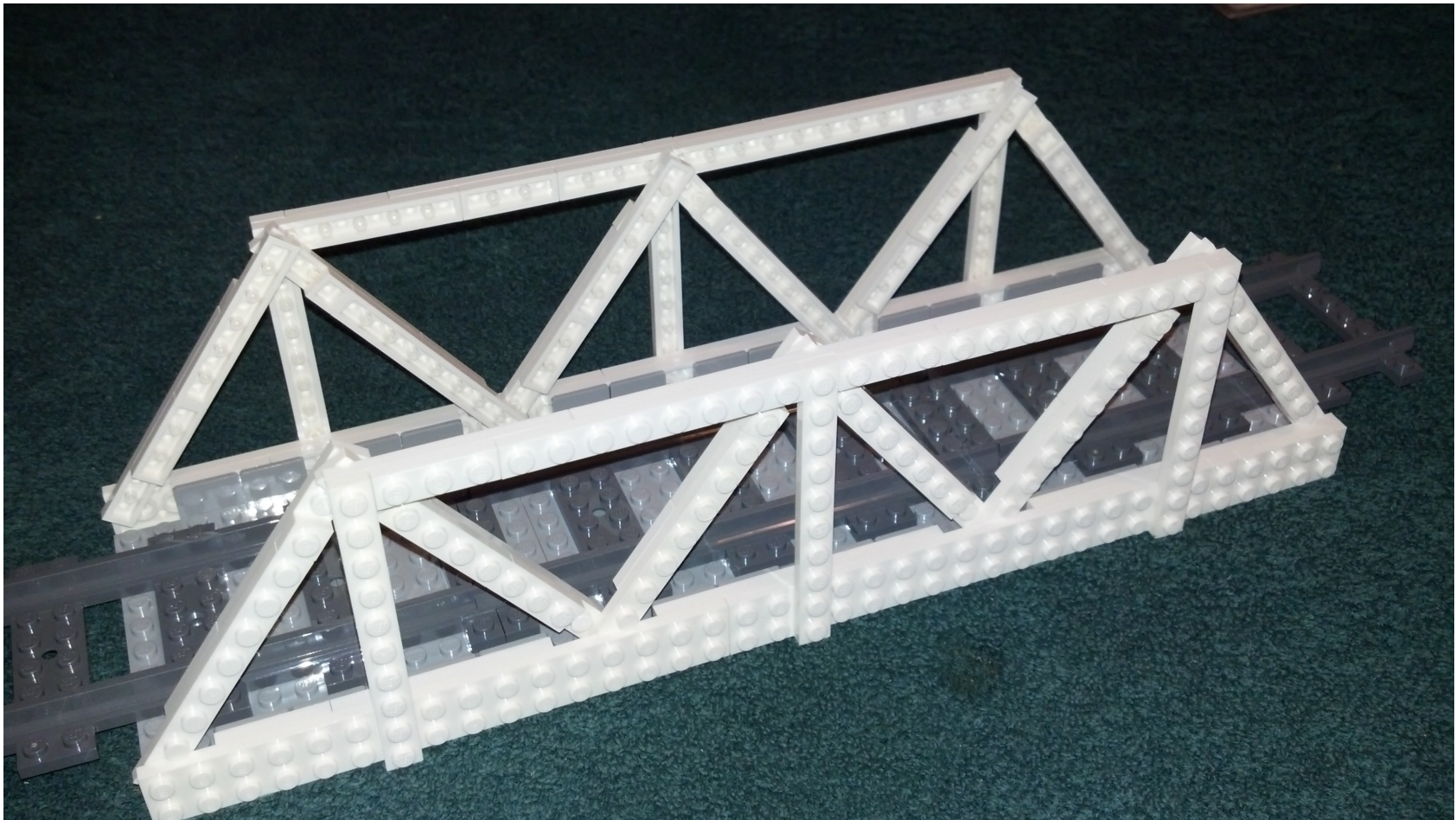
Note: You may need spacer plates for the diagonal to clear the studs.

More Pythagorean Triples

- There are only 4 triples with the diagonal of length 25 or less:
 - (3, 4, 5); (5, 12, 13); (8, 15, 17); (7, 24, 25)
- Additional ones can be made by multiplying these values by a scaling factor.
 - Example: $(6, 8, 10) = 2 \times (3, 4, 5)$
- Any other triangle with integer sides will *not* be a right triangle!

Pythagorean Triple Example: Truss Bridge

Trusses made from (6, 8, 10) Pythagorean triangles



Additional Resources

- “Offset” page on brickwiki
<http://www.brickwiki.info/wiki/Offset>
- Reinhard Beneke, BrickFest PDX '04
<http://www.brickshelf.com/cgi-bin/gallery.cgi?f=74539>
- Previous versions of this presentation:
 - BrickCon 2008: Half Plate Offsets
<http://www.brickpile.com/2008/10/07/half-plate-offsets-slides/>
 - BBTB 2013 & BrickCon 2013: Brick Geometry
<http://www.brickpile.com/2013/10/17/slides-for-brickcon-brick-geometry-presentation/>



Q&A



Thank you

Contact me if you have any further questions...

bill@wards.net

www.brickpile.com

Come to Bricks by the Bay!

August 7-10, 2014

Santa Clara, California

www.bricksbythebay.com