

Brick Geometry & SNOT Building



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Presented at BayLUG October 23, 2022 www.baylug.org



Ratios and Dimensions

Basic LEGO Geometry

- Height of 1 brick = 3 plates
- You knew this already, I assume...



Math is hard!



LDU: LDraw Unit

- A 1x1 stud brick or plate is 5/16" or 8mm (0.8cm)
- The height is 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!



Unit Conversions

unit	LDUs	studs	bricks	plates	mm	inches
1 LDU =	-	0.05 (1/20)	0.04167 (1/24)	0.125 (1/8)	0.4	~0.016" (~1/64")
1 stud =	20	-	5/6	2.5	8.0	~0.315" (~ ⁵ / ₁₆ ")
1 brick =	24	1.2 (⁶ / ₅)	-	3	9.6	~0.378" (~³/ ₈ ")
1 plate =	8	0.4 (²/ ₅)	0.333 (¹ / ₃)	-	3.2	~0.126" (~1/8")
1 mm =	2.5	0.125	0.104	0.3125	-	~0.039 (~³/ ₆₄ ")
1 inch =	63.5	3.175	~2.65	~7.94	25.4	-

LEGO Bricks Are Not Square

- Bricks are 8mm wide by 9.6mm high ... but 9.6 is not an integer
- LDU makes all values integers

5 plates = 5x8 = 40 LDU 2 studs = 2x20 = 40 LDU



6:5 Brick Ratio

5 bricks = 5x24 = 120 LDU 6 studs = 6x20 = 120 LDU





Even Number of Studs



- Even number of studs = integer number of plates
 - 6 studs = 15 plates = 5 bricks
 - 4 studs = 10 plates = $3\frac{1}{3}$ bricks
 - 2 studs = 5 plates = $1\frac{2}{3}$ bricks
 - 2n studs = 5n plates
- If n is also divisible by 3 then you also have an integer number of bricks.

Odd Number of Studs

- Odd number of studs cannot be equal to integer number of plates!
 - 1 stud = 2 $\frac{1}{2}$ plates
 - 2 stud = 5 plates = 1 brick + 2 plates
 - $3 \text{ stud} = 7 \frac{1}{2} \text{ plates}$
 - 5 stud = 12 $\frac{1}{2}$ plates
 - 2n+1 studs = $5n+2\frac{1}{2}$ plates
- ... so how do you fill that ½ plate?







Half Plate = Bracket



- All members of this family of brackets have a half-plate vertical part (4 LDU)
- Combine this with 2 plates + to make up the missing half plate!
 - 8 * 2 LDU + 4 LDU
 - = 20 LDU
 - = 2 studs

#notallbrackets

- The "neck brackets" that a minifig can wear have a thickness closer to 3 LDU
- Not a full $\frac{1}{2}$ plate thick, so not useful for this trick.



SNOT: Studs Not On Top

Brackets as ¹/₂ plate

Bracket: 4 LDU (1/2 plate) Red plate: 8 LDU Tile: 8 LDU Total: 20 LDU (same as 1 stud)



Bracket's vertical part is $\frac{1}{2}$ plate thick (4 LDU).

Tile's face is flush with the edge of the white 2x2 plate.

SNOT Bricks: Bricks/plates with studs on their side(s)

LEGO has made many parts over the years with studs on the side(s), useful for SNOT (Studs Not On Top) design. Which are your favorites?



Can we use TECHNIC for SNOT?

- Short Answer: **Yes**. Technic half-pin provides a stud on a Technic brick, or press studs into holes.
- Long Answer: No. Alignment of Technic pin holes is not quite correct...







The Problem with TECHNIC for SNOT

TECHNIC bricks in the 1970s were made with holes a little too high in order to make space for studs in bottom of bricks. Injection molding technology has improved since then but we are stuck with the design.



Using TECHNIC bricks for SNOT results in slight misalignments



Adding SNOT Bricks: 2 + 2 = 5

- White "Plate, Modified 2 x 2 x 2/3 with 2 Studs on Side" (part 99206)
 = 2 plates high
- Grey "Brick, Modified 1 x 2 with Studs on 1 Side" (part 11211)
 - = 3 plates high
- Total
 - = 5 plates high= 2 studs wide



Flush mount with SNOT bricks



- Use bricks with studs on sides to attach assemblies at 90 degrees.
- To mount them flush, just remember that 5 plates = 2 studs = 40 LDU.
- 3 bricks thick isn't too great, but we can do better.

Flush tile: Lunar School Bus

Grille and headlight sub-assembly is made of 4 plates and a tile, and fits in a 2-stud space

5 plates = 40 LDU = 2 studs



Another Example: Sheep

- Sheep's neck is made from a brick and two plates = 40 LDU
- A 2x2 plate fits on the top of the neck and the studs are "in system" with the rest of the body.





Inset Panels: Deliberately misaligned

- On my Caltrain locomotive, I used halfplate offsets to add texture (access panels) to an otherwise flat wall.
- Tiles are inset by ½ plate.



Inset panels on the Caltrain locomotive



Panels recessed ¹/₂ plate

Photo by Drew Dirschell: https://www.flickr.com/photos/7333042@N06/4639456044

"De Vier Gekroonden" by Vincent Kessels

- Model by Vincent "Mr. Tomato Bread" Kessels
- House in Gouda, NL, built ca. 1530 CE
- "De Vier Gekroonden" means "The Four Crowned Martyrs"



Vincent's photos and design used with permission.

Sideways Building with Brackets



- Light blue stripe made from stacked bricks/plates/tiles attached to 1x2-2x2 brackets on either end.
- Each half contains 3 bricks (72 LDU), 7 plates (56 LDU), a tile (8 LDU), and bracket (4 LDU).
- Total = 140 LDU = 7 studs. With a brick added to each end, it fills the 16 studs of the façade.

Model: "De Vier Gekroonden" by Vincent Kessels

Problem with Jumper Plates

- To line the 6-stud arches up with the 5-studs wide windows, need to use jumper plates to create ¹/₂ stud offset
- Cannot fill ¹/₂ stud offset with SNOT! Gap 10 LDU but tile is 8 LDU, leaving ¹/₄ plate short.

by Vincent Kessels

• But it's an old building, so he didn't mind too much...



Fun with Headlight Bricks

Headlight Brick Dimensions

Height = 20 LDU height of 1 brick or 3 plates

Depth = 16 LDU height of 2 plates

"Foot" = 4 x 4 LDU 1/2 plate x 1/2 plate

Four headlight bricks

 2 plates + 3 plates = 5 plates, in each direction



Combining Brackets & Headlight Bricks

1/2 plate from Bracket + 1/2 plate from headlight brick's "foot" = 1 plate



As seen in the LEGO IDEAS Ghostbusters set #21108 (minifig display)

A Problem: Gradual Steps



Problem: you want a gradual slope without the jarring 1-plate steps

Gradual Steps



Solution: ½ plate offset between steps But how to attach the parts?

Headlight Bricks to the Rescue



Alternate studs-up and studs-sideways headlight bricks to take advantage of 1/2 plate offset in "foot" (2 plates + $\frac{1}{2}$ plate = 1 stud)

Stairstep effect with Slopes

With slopes we can have the same problem due to the step up at the bottom of the diagonal.

There is a "step" in order to fit a stud inside

Stairstep effect with Slopes

The "step" in the slope pieces is exactly ½ plate high (4 LDU)!

2 plates + slope step matches width of 1-studwide brick

Solving the stairstep effect

Use headlight bricks to provide smooth transitions



Example: Bram Lambrecht's "Legoland Spacelines 979"

http://www.flickr.com/photos/bram/1461137007/ Photo used with permission

Useful for trains, too



My Caltrain F40PH locomotive uses this technique in 2 dimensions for the double angle in the nose.

"Headlight Brick" vs. "Brick 1 x 1 with Stud on 1 Side"

- Yellow headlight brick depth = 2 plates = 16 LDU
- Red brick depth = 2 ¹/₂ plates = 20 LDU
- Combine these to achieve ¹/₂ plate differences in depth!



Hospital Bay Window example

In my Micropolis hospital, alternating direction headlight bricks hold bricks with studs on one side to produce a bay window and balcony effect. The "windows" (exposed bottoms of bricks) are inset by ½ plate from the tile beneath.



How about QUARTER plate offsets?



- Jumper = ½ stud offset (10 LDU)
- Like we saw on Vincent's house we can get a 2 LDU gap by combining this with sideways plates (8 LDU)

 Each step on this model is only ¼ plate difference (2 LDU)!

Triangles

Pythagorean Triples

4

- Pythagorean Theorem: a² + b² = c² True for any *right* triangle (one corner is 90°)
- Triangles that fit this equation with integers are "Pythagorean Triples," *e.g.*:
 - 3, 4, 5
 - 5, 12, 13
 - 8, 15, 17
 - 7, 24, 25



Multiples of Pythagorean Triples

4

- Double, triple, etc. every side of a Pythagorean triple to make another one
 - 3, 4, 5
 - 6, 8, 10
 - 9, 12, 15
 - 12, 16, 20
 - etc...



Pythagorean Triples in LEGO

- When making a Pythagorean Triple in LEGO, add one stud to each side
- Why? Count distance between the middles of *each corner stud*
- (3, 4, 5) triangle = (4, 5, 6) studs
- (6, 8, 10) triangle = (7, 9, 11) studs



5 studs = length 4

More Pythagorean Triples in LEGO



More examples showing how you add 1 to each side

- (5,12,13) triangle = (6, 13, 14) studs
- (8, 5, 17) triangle = (9, 6, 18) studs

Actually building these triangles

Studs will get in your way. You must either make the triangle with smooth parts, such as the 1x4 with only 2 studs, a Technic design, or insert spacer plates as we have done here. This makes the triangle at least 3 plates thick.

Pythagorean Bridge



Trusses made from (6, 8, 10) Pythagorean triangles LEGO model uses (7, 9, 11) studs

Triangles from Hinges



- Not exactly a triangle, but if you add a hinge to one side you can get a lot more sizes.
- For more information including a list of possible angles, see "Hypo-technique 1" from Sir Bugge's Lego Page website, at the link below:

http://www.l3go.bugge.com/articles/technique/Hypotech1.shtml

Swap Corners Technique

- Two identical rectangles have identical diagonal lengths
- You can therefore rotate one relative to the other so the opposite corners touch
- In LEGO, you can do this by connecting the corner studs



Swap Corners Example

You can even mount an entire building this way...



Swap Corners using Hinges

- A related technique can be done using hinges, since the rotation point of the hinge is exactly on the corner of the brick.
- Example: tapered rear of fuselage on LEGO aircraft such as Sopwith Camel (set 10226)







Studs in All Directions

Travis Brick



- a.k.a. "Brick, Modified 1 x 1 with Studs on 4 Sides"
- Named the "Travis Brick" by the LEGO fan community after the late Space builder Travis Kunce, who had it tattooed on his arm
- Many "Studs on All Sides" techniques use this piece

Photo by Travis Kunce https://brickshelf.com/cgi-bin/gallery.cgi?i=522387

Lowell Sphere

- How do you build a sphere out of LEGO?
- Solution designed by Bruce Lowell for a 6.8-stud diameter sphere (4 studs + 6 plates)
- Common basis for studs-on-all-sides MOCs





Bram's Sphere Generator



Bram Lambrecht wrote a program to generate LDraw instructions for a Lowell Sphere of any diameter

http://lego.bldesign.org/sphere/

Old LEGO IDEAS Globe project

- Globe design submitted by "WWWally" in 2012, only got 699 votes
- Based on Lowell Sphere design
- https://ideas.lego.com/ projects/16205





No, not this one!

Travis Brick Not Required



- Any SNOT parts can be used instead of Travis bricks if it fits
- If using old-style jumper plates, center them on hollow studs

Some of my Lowell Sphere based MOCs

Christmas Ornaments

Sheep

Kermit's eyes





Easter Eggs







Breaking Eggs: Going from Sphere to Oval



The round end (bottom) of egg is the same as on a standard Travis Sphere



The pointy end (top) of the egg is my original design

The sides (2 of each version) are the same as on a standard Travis Sphere but with one edge extended



Coloring Eggs

This egg has the *exact same shape* as the white one, but to get the colors to work, and to work around the limited range of parts in pink, the structure is very different!









Taking it to the Next Level

My Easter Bunny, Stay-Puft, and Teddy Bear were built in a similar way, just not a spherical shape...







Miscellaneous Brick Techniques

DSnot



- "DSnot" technique from swooshable.com shows a fun use of the 1x2 hinge
- Any hollow stud parts work on ends. I replaced one hinge with a "Plate, Modified 1 x 2 Rounded with 2 Open Studs" (Part 35480)
- Hinges can still be rotated!

Surprise 45° Connection

- Brick, Round 2 x 2 with Flutes (Grille) and Axle Hole (92947) fits on studs at a 45 degree angle!
- Due to the "flutes" the cutouts in the corners on the bottom are just the right size
- Does not work with smooth round parts



Another Weird & Illegal 2x2 Round Part Connection



- Old-style 2x2 round tile with "cross" (and the version with Lifting Ring) can attach upside-down to any 1x1 square part
- Modern 2x2 round tile has a circle on the underside instead which does not work with this trick.



Additional Resources

Reinhard Beneke, BrickFest PDX '04

http://www.brickshelf.com/cgi-bin/gallery.cgi?f=74539

Sir Bugge's Hypo-Techniques (triangles from hinges)

http://www.l3go.bugge.com/articles/technique/Hypotech1.shtml

The New Elementary, blog about new parts https://www.newelementary.com/

Swooshable, website about clever building techniques

https://swooshable.com/

Bruce Lowell's "Lowell Sphere" page http://www.brucelowell.com/lowell-sphere/

Bram Lambrecht's sphere generator http://lego.bldesign.org/sphere/

Slides from this talk and earlier versions, on my website https://www.brickpile.com/articles/brick-geometry-presentations/

My website https://www.brickpile.com/

Thank You!



Contact me if you have any further questions...

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