## Brick Geometry

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


## LEGO Bricks Are Not Square

Bricks are 8 mm wide by 9.6 mm 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 studs $=5$ plates


4 studs =
$31 / 3$ bricks = 80 LDU (or 10 plates)

2 studs =
$12 / 3$ bricks = 40 LDU
(or 5 plates)

## Odd Numbers of Studs

Since 1 stud = 21122 plates, no combination of plates adds up to exactly one stud


1 stud = 20 LDU
2 plates = 16 LDU ?? = 4 LDU
(Missing $1 / 2$ plate!)

3 studs = 60 LDU
1 brick +4 plates $=56$ LDU

$$
? ?=4 \text { LDU }
$$

(Missing ½ plate!)

2 stud = 40 LDU
5 plates $=40$ LDU
(OK)

## But where do you get $1 / 2$ plate?

One answer: brackets. The thin vertical plate is $1 / 2$ the thickness of a normal plate, or 4 LDU


## SNOT

Studs Not On Top

## Using $1 / 2$ plate thickness from brackets



## 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 $1 / 2$ pin is not quite the same - see next page


## Caveat - Technic Pin Alignment



VS.


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, so hole was moved up.
Result: LEGO now produces more bricks with studs on side instead of using $1 / 2$ 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



## Inset Panels

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


Tiles are $1 / 2$ plate inset

1 plate +2 studs (1 2/3 brick) $=2$ bricks

2 plates +4 studs (3 1/3 bricks) $=4$ bricks

## Inset panels example



My F40PH Caltrain locomotive

## "De Vier Gekroonden"

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

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## Sideways Building with Brackets



Stack bricks and plates with a tile on the end Mount on bracket on each side facing inward 3 bricks $=3 \times 24=72$ LDU
Model:
"De Vier Gekroonden" by Vincent Kessels a.k.a.
"Mr. Tomato Bread"

7 plates +1 tile $=8 \times 8=64 L D U$
bracket = 4 LDU
Total = 140 LDU = 7 studs
Tiles on the ends press together and friction holds it all together

## The Problem with Jumper Plates

Requirement: 5 -stud wide window openings with 6 -stud wide arches above.
Solution: offset the arches by $1 / 2$ stud using jumper plates
Side effect: How to fill $1 / 2$ stud gap on ends?
Imperfect solution: attach tile mounted sideways.
$1 / 2$ stud $=10$ LDU. Tile $=8$ LDU. Gap of 2 LDU ( $1 / 4$ 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.

## Combining Brackets \& Headlight Bricks

$1 / 2$ plate offset on headlight bricks +<br>$1 / 2$ plate thickness on bracket =<br>1 plate thickness, suitable for new curved slope



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

## 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 $1 / 2$ 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 $1 / 2$ plate offset in "foot"

2 plates $+1 / 2$ plate $=1$ stud


Half-plate lift from "foot"

## Problem with "cheese slope": Stairstep effect



> The $1 \times 1$ "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 $1 / 2$ plate thick.

2 plates (height of cheese slope) $+1 / 2$ plate

$$
=1 \text { stud }
$$

## Solving the stairstep effect



## Used in Bram Lambrecht's <br> "Legoland Spacelines 979"

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 $1 \times 1$ with Stud on 1 Side"

Headlight Brick depth $=2$ plates $=16$ LDU
Brick depth $=21122$ plates $=20$ LDU
Combine these to achieve $1 / 2$ plate differences in depth!


## Hospital Bay Window example

Windows (bottoms of bricks) are inset by $1 / 2$ 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: $(6,8,10)=2 x(3,4,5)$
- 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 http://www.brickpile.com/2013/10/17/slides-for-brickcon-brick-geometry-presentation/
- 2014: Brickworld \& Bricks by the Bay \& BrickCon

Q\&A

## Thank you

Contact me if you have any further questions...

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