Particles: Orientation and Density

Lecture #6

Two schools of thought

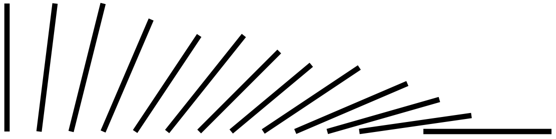
- Some distortions in the body during drying and firing can be explained by two different theories…

  1- Orientation of clay platelets

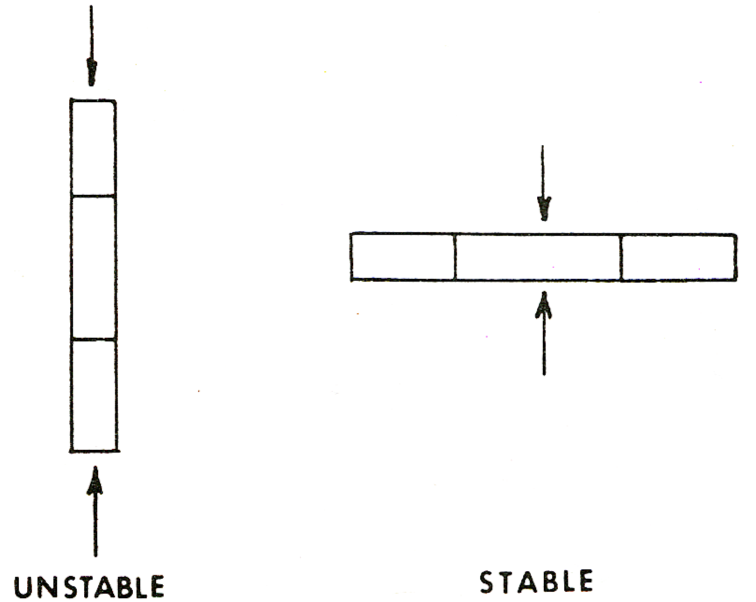
  2- Density differences within the body

The two are interrelated; neither occurs exclusively

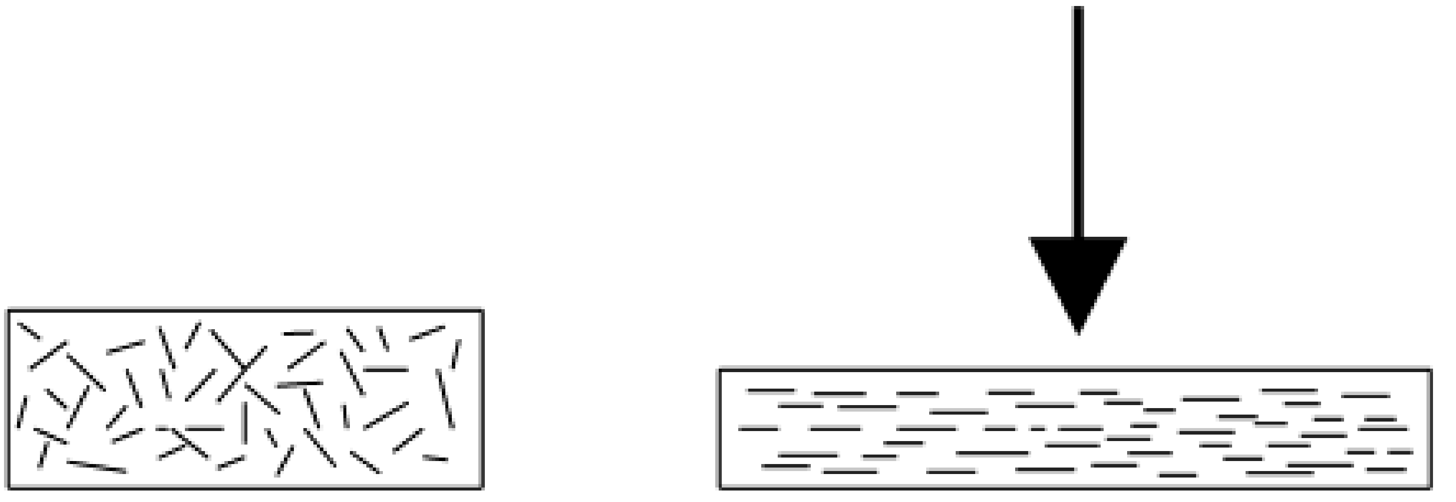
Orientation



- The orientation of particles in a piece affects workability, shrinkage, drying and firing characteristics
- Understanding particle orientation during the forming process can help predict warping during drying and firing

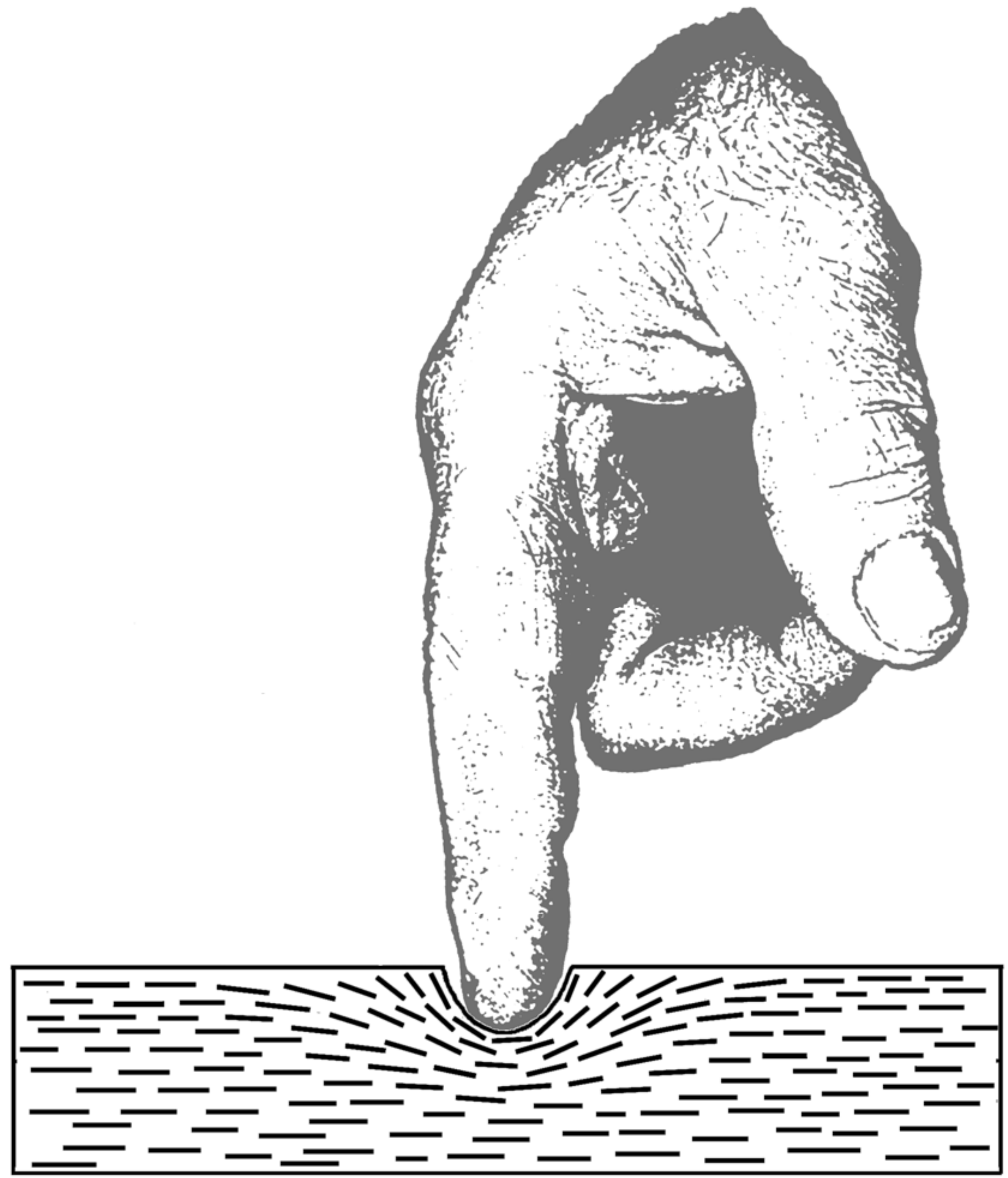


- Plate-like particles align perpendicular to applied forces to achieve stability

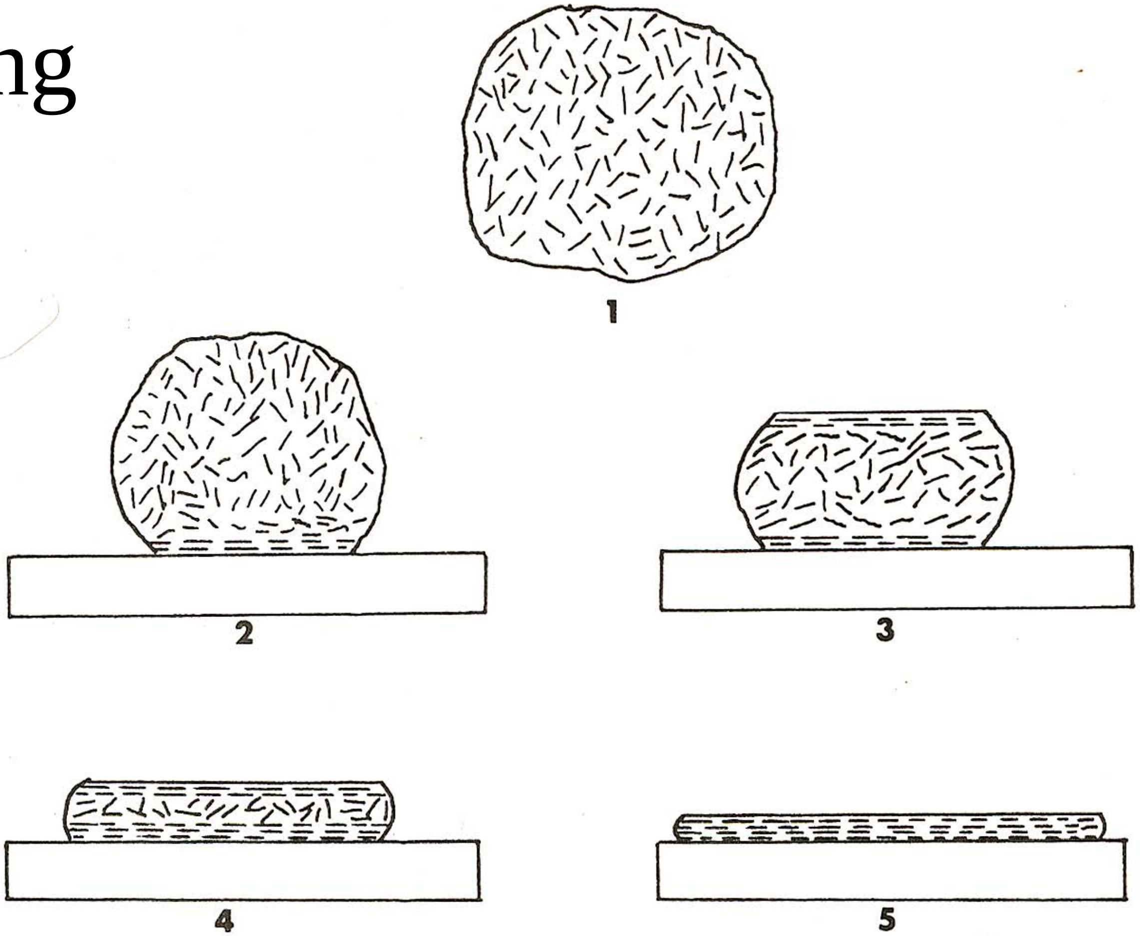


- Clay particles in a body align perpendicular to their applied force
  - Compression → Re-orientation

- Every time we impress a plastic body, particles are re-aligned
- Notice that the re-alignment effect on particles is a gradient which diminishes over distance

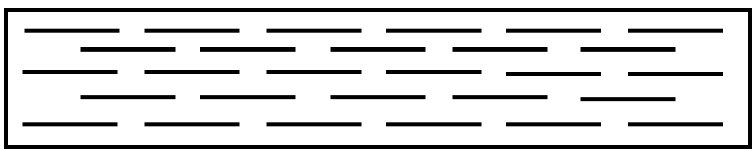


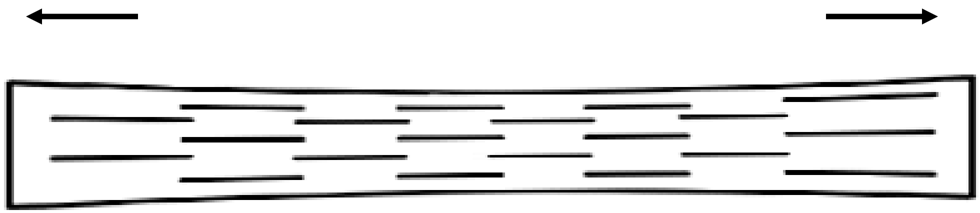
Reorientation due to repeated dropping of a clay mass



Mass must be alternately flipped to ensure parallel alignment on both sides

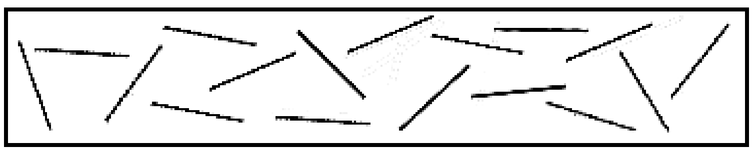
- Parallel alignment of particles
  - Allows for increase in extension among particles
    - Particles can travel further before hyper extending
    - Clay holds on longer





•Workable

extension



•Un-workable

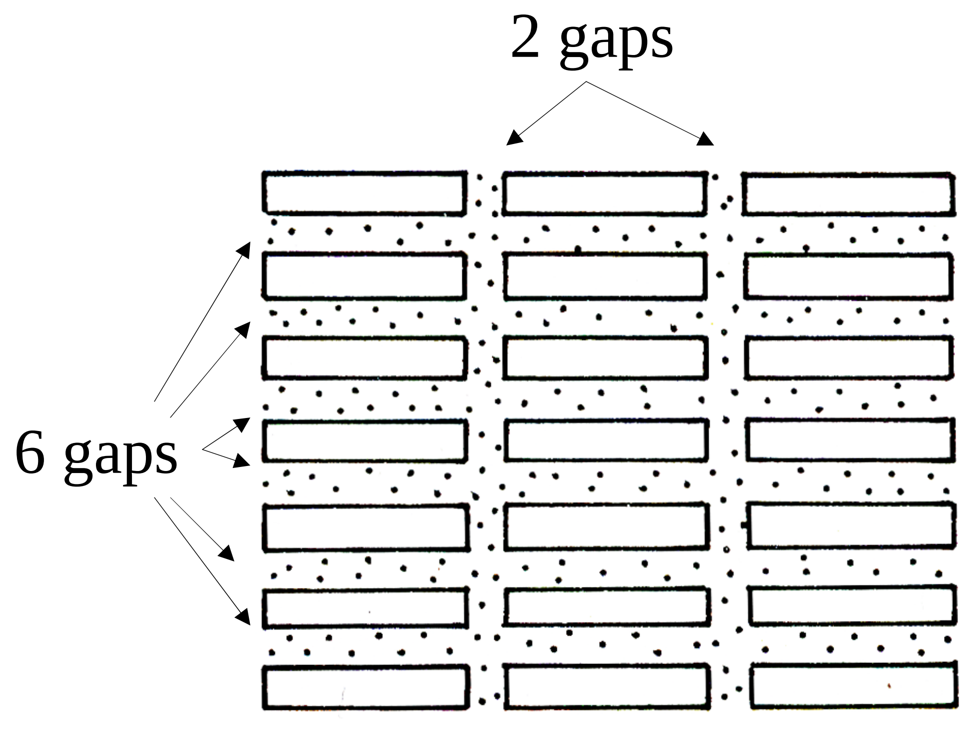
hyper extension

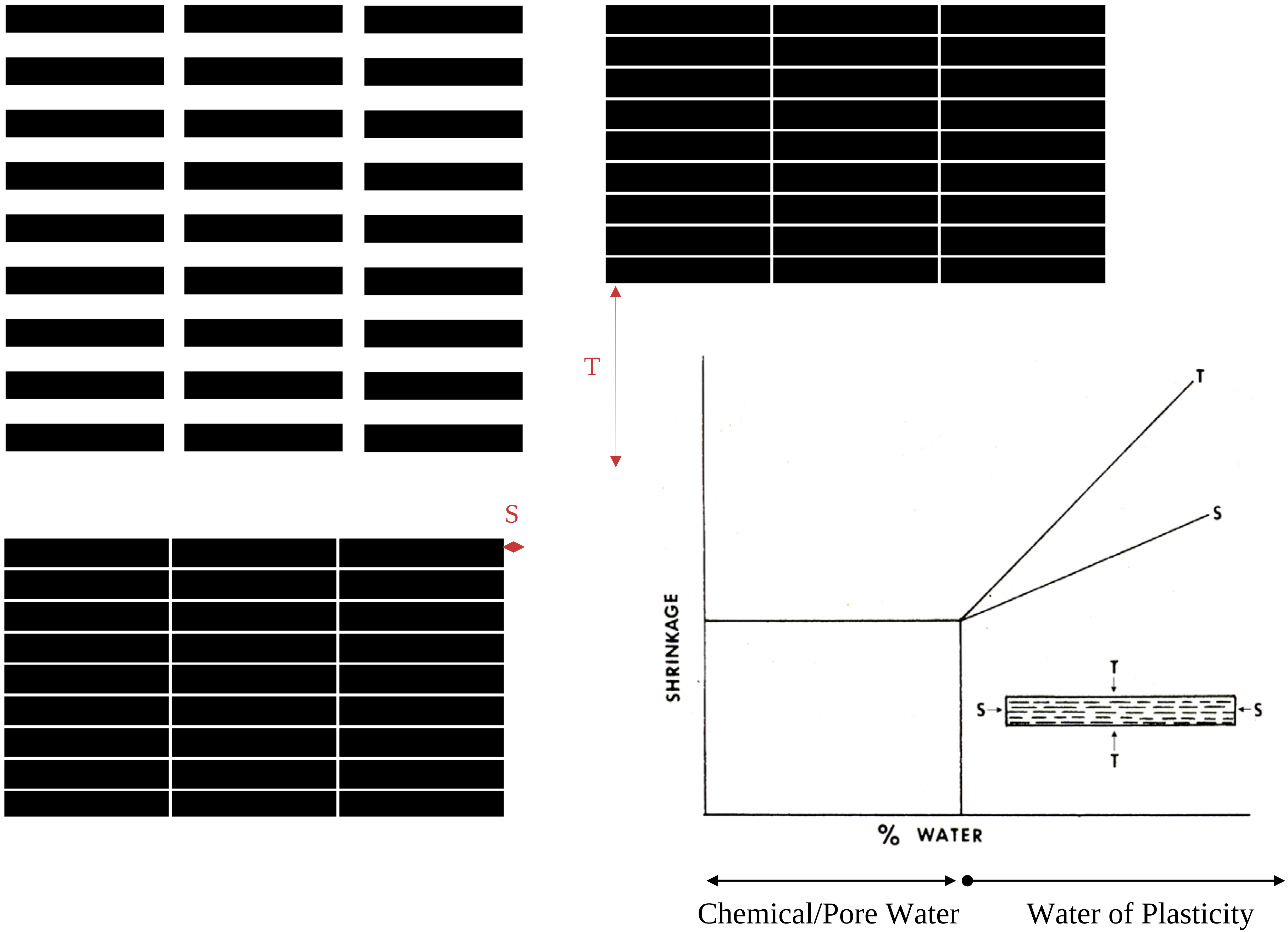
Parallel Alignment of Particles

- Increases strength
  - surface contact among particles is increased
- Increases plasticity
  - allows the clay body to be stretched, pulled, and/or bent further before cracking
- Can be achieved by hitting (compressing) clay with mallet or other flat tool
- So… workability is a function of material selection, proper mixing **and** particle alignment

Differential Shrinkage

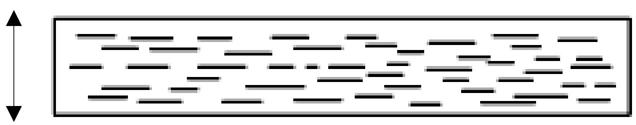
- Particle orientation affects drying and firing shrinkage
  - Shrinkage is greater in height than in width (assuming all particles are parallel)
    - Greater amount of total gaps in vertical orientation = greater dry and fired shrinkage in the vertical dimension



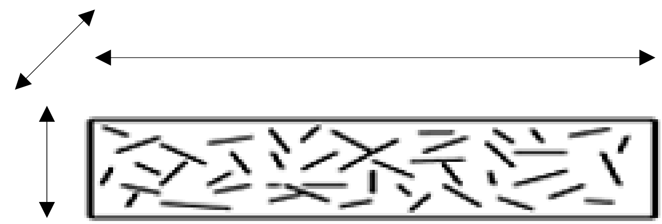

T
S
SHRINKAGE
% WATER
T
S
T
S
S
T
Chemical/Pore Water
Water of Plasticity

Reducing Differential Shrinkage

- By randomizing particle orientation, differential shrinkage may be reduced



High differential shrinkage



Reduced differential shrinkage
(no preferred direction of shrinkage)

Random particle alignment simplifies drying and firing

So…

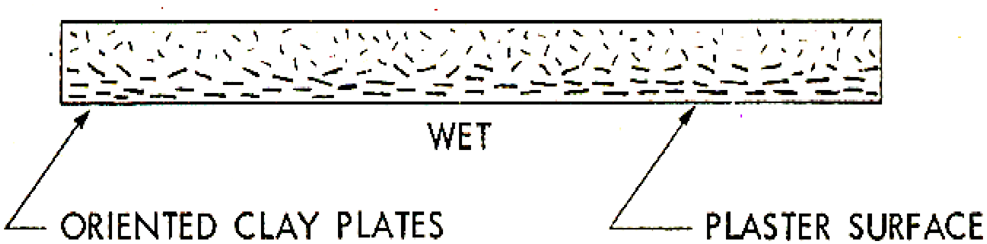
- Parallel particle orientation
  - Increases workability
  - But also increases differential shrinkage

- Random particle orientation
  - Decreases workability
  - But reduces differential shrinkage

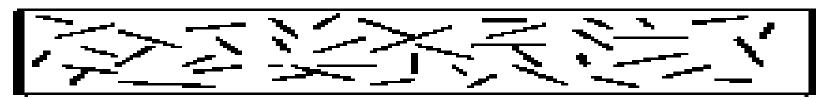
- Neither state is exclusively achieved
  - Forming techniques promote varying degrees of each condition

- Both slurry and plastic mixing present unique variables which must be compensated for

From slurry



From dough mixer



Slurry mixing

Moisture is unevenly distributed during drying

Moisture must be redistributed evenly

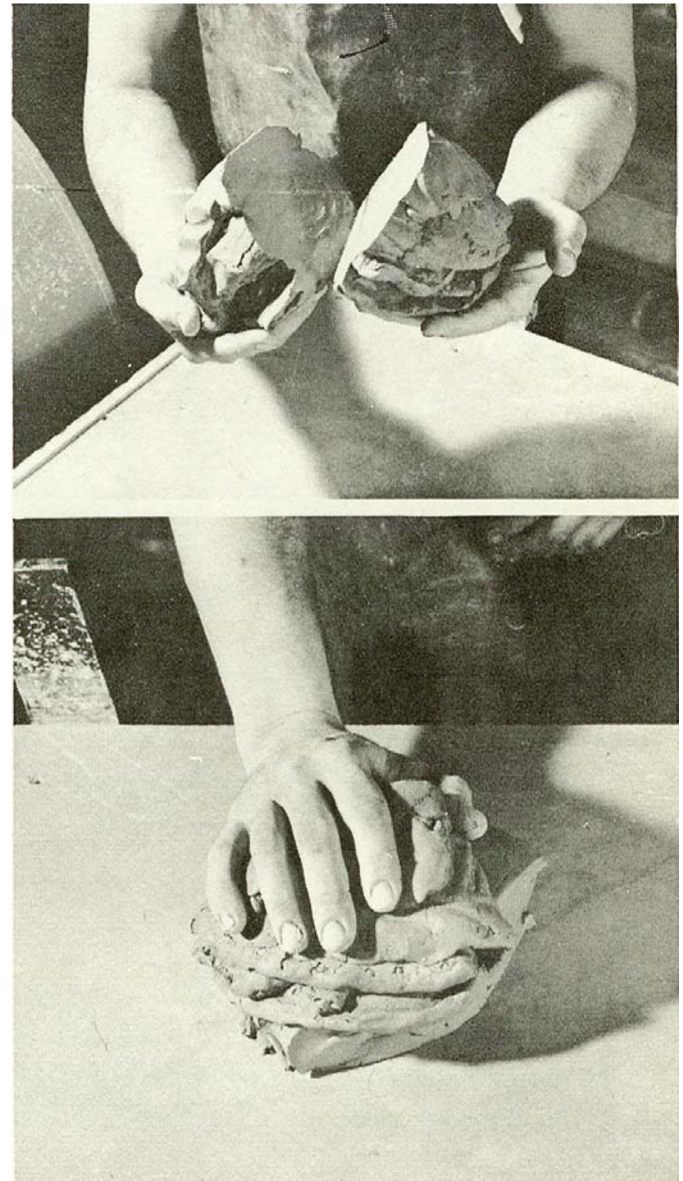
Plastic Mixing

Particles are loosely held together / air pockets are present

Particles must be reoriented and de-aired

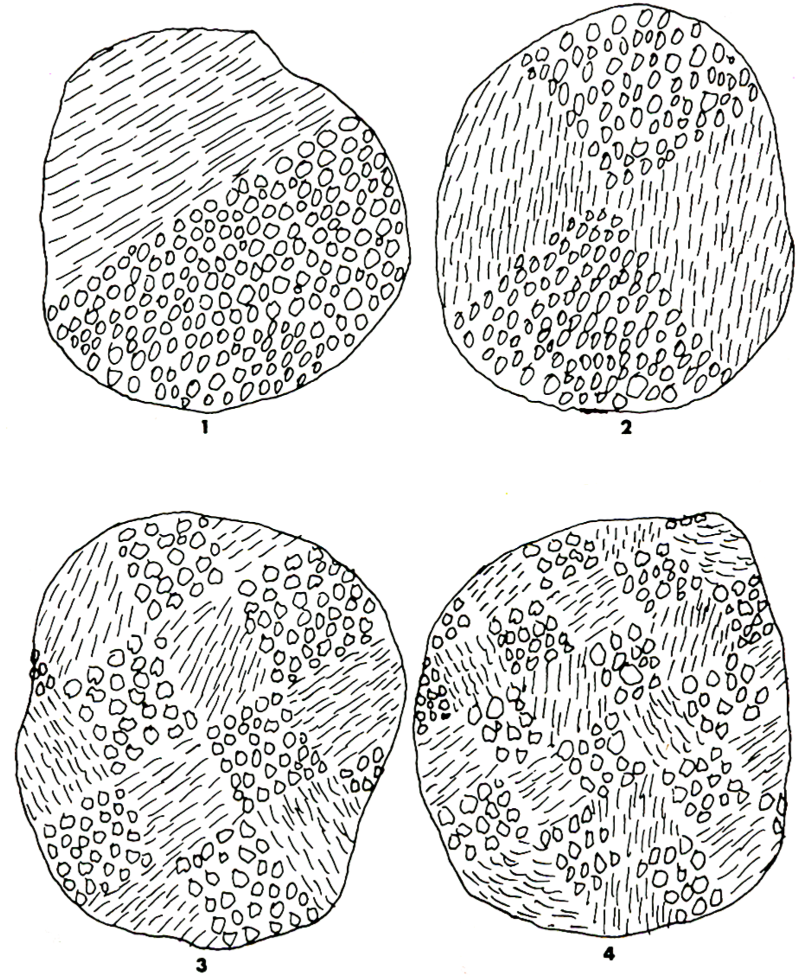
Cutting and Slamming

- Clay mass is wire cut, rotated/flipped, and slammed together
  - Air pockets are removed
    - Decreased void space (increase particle contact)



Orientation Effects of Cutting and Slamming

- Randomizes particle orientation
- Useful when building-up solid blocks to be hollowed out latter
  - Avoids spiral orientation caused by kneading and/or pugging



Spiral Kneading

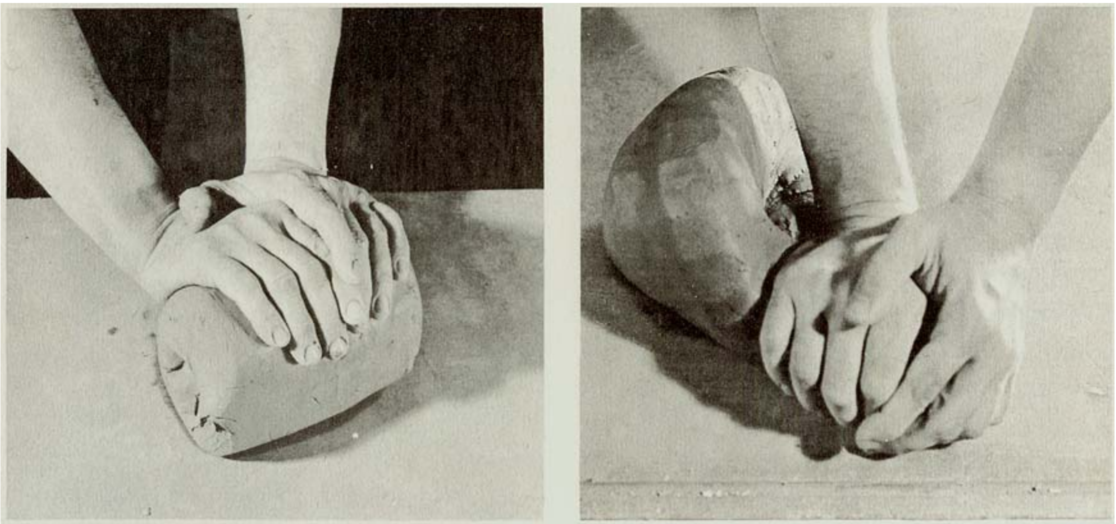
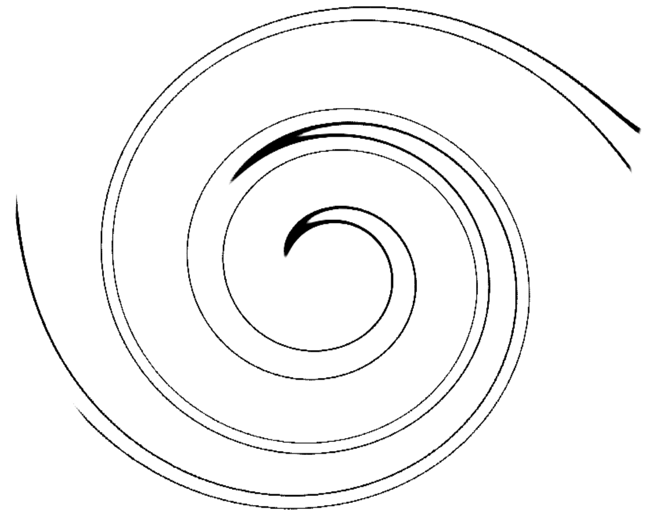


Fig. 18-18. "Jelly-roll" wedging: the roll is deformed by the pressure of both hands, turned 90°, and pressed again.

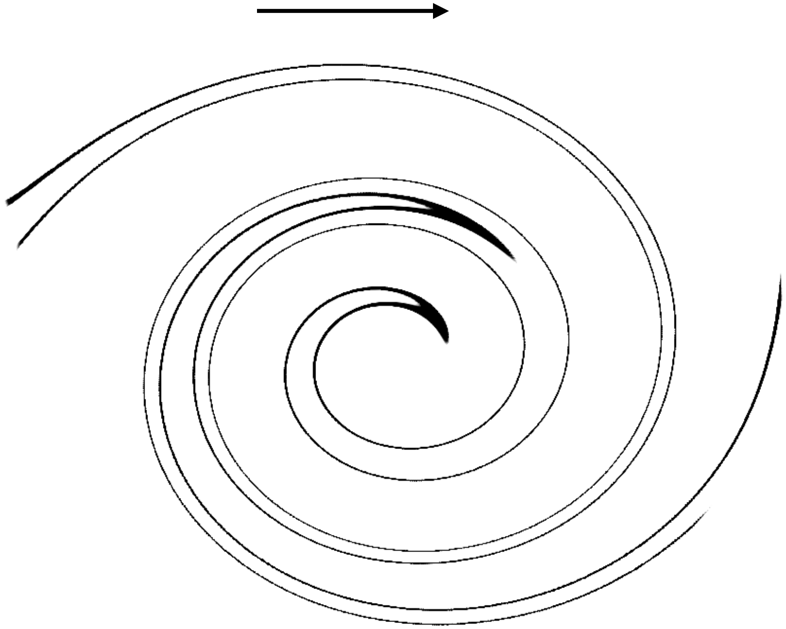
Fig. 18-19. Oriental wedging: the rhythmic pressure from the right hand makes the clay flow around.

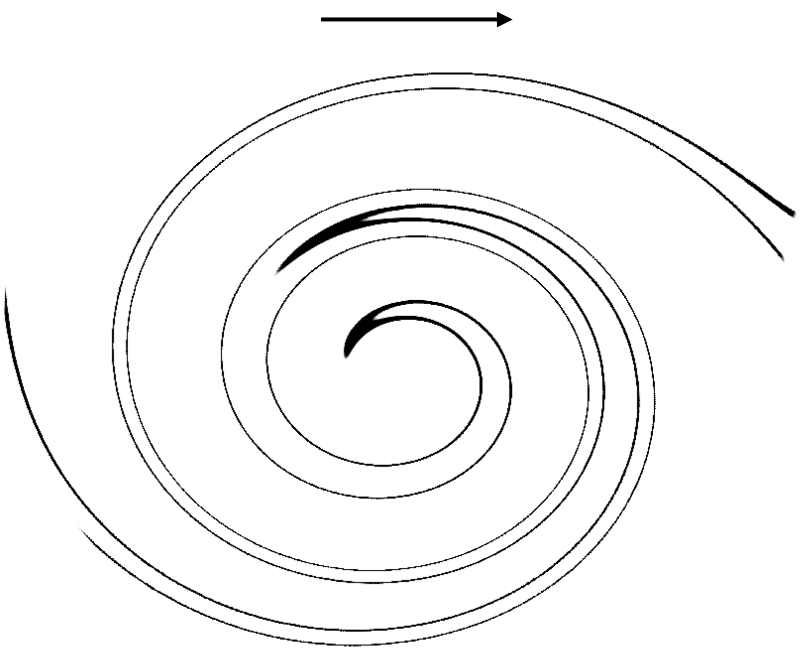


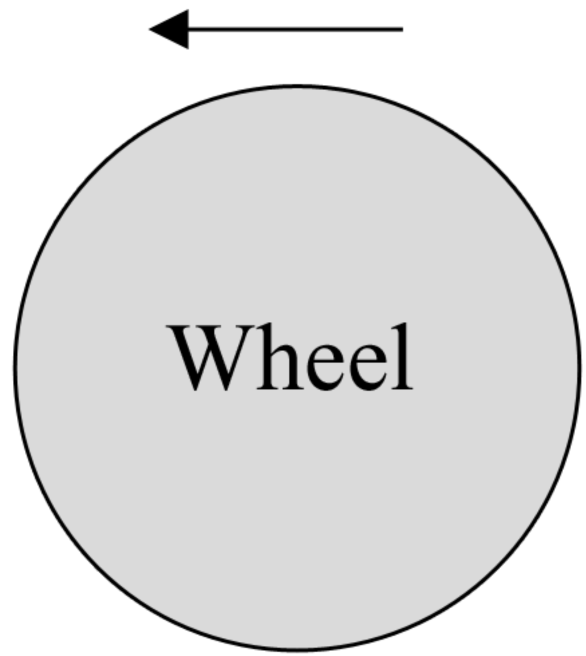
- Very oriented
  - Particles align in a spiral direction
- Ideal for throwing
  - The circular motion of throwing reflects this spiral orientation

Orienting spiral relative to wheel movement

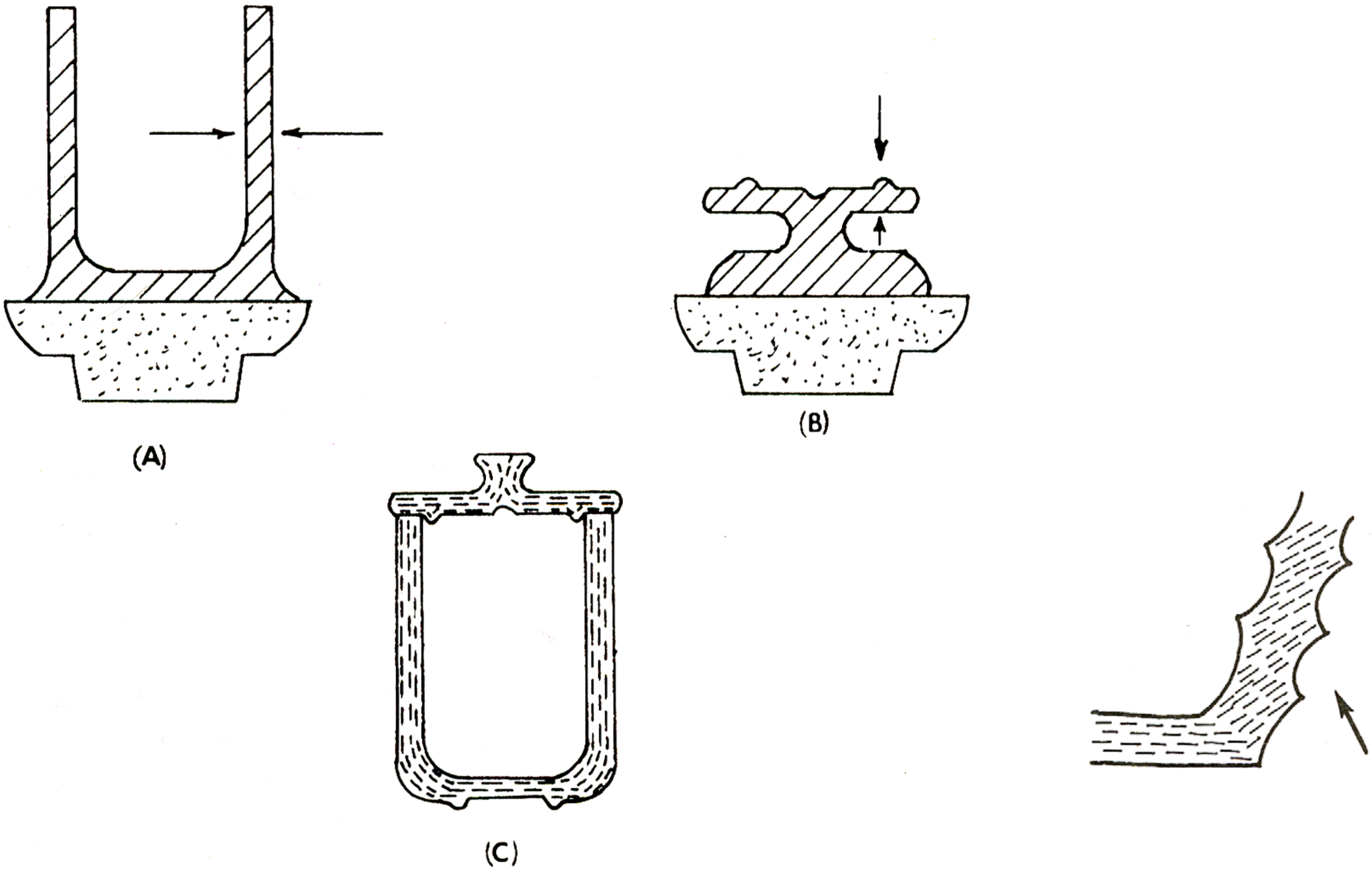
Does one orientation help more than the other?



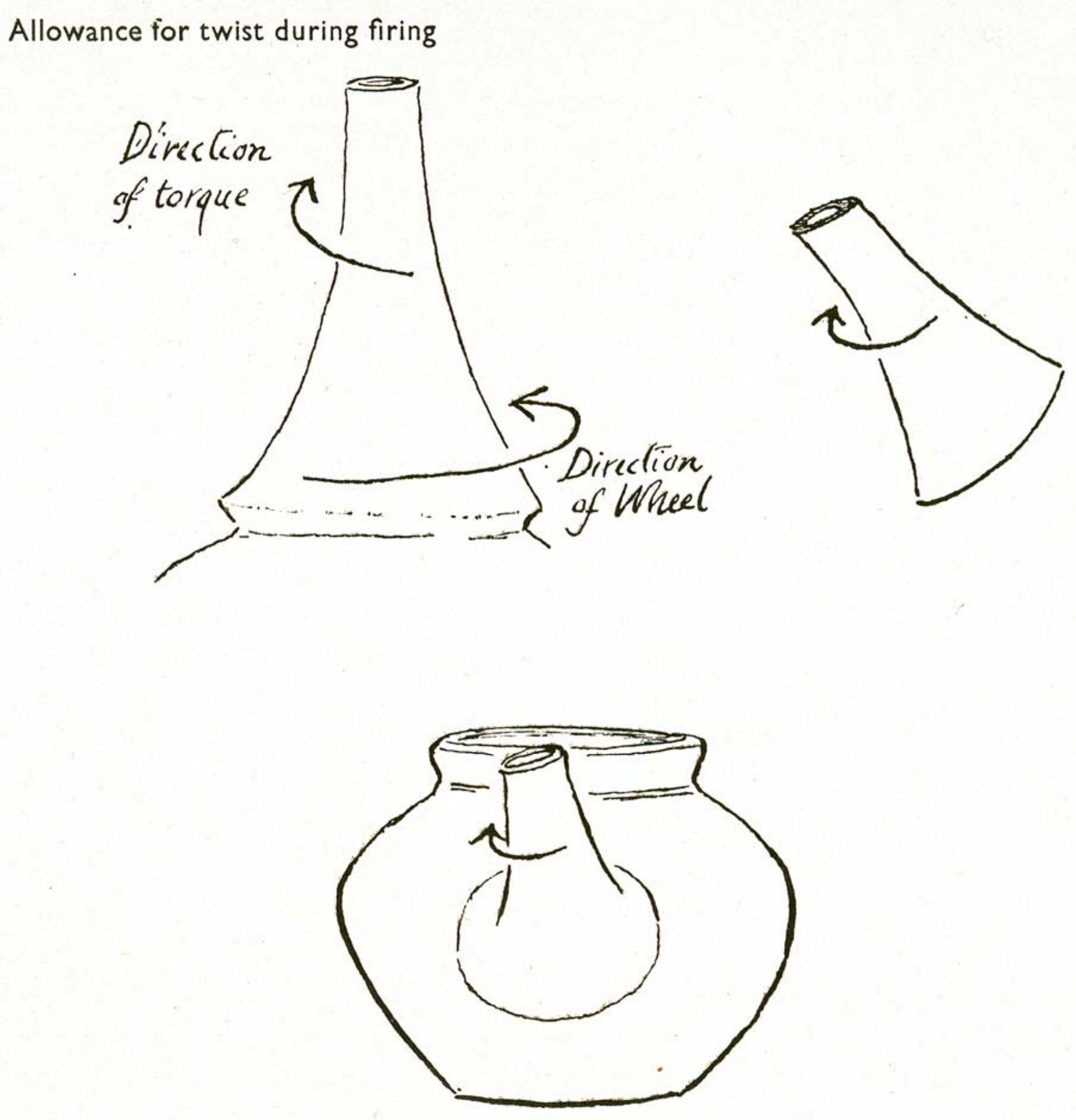




Orientation Effects Of Throwing



Forces applied during throwing orient the particles



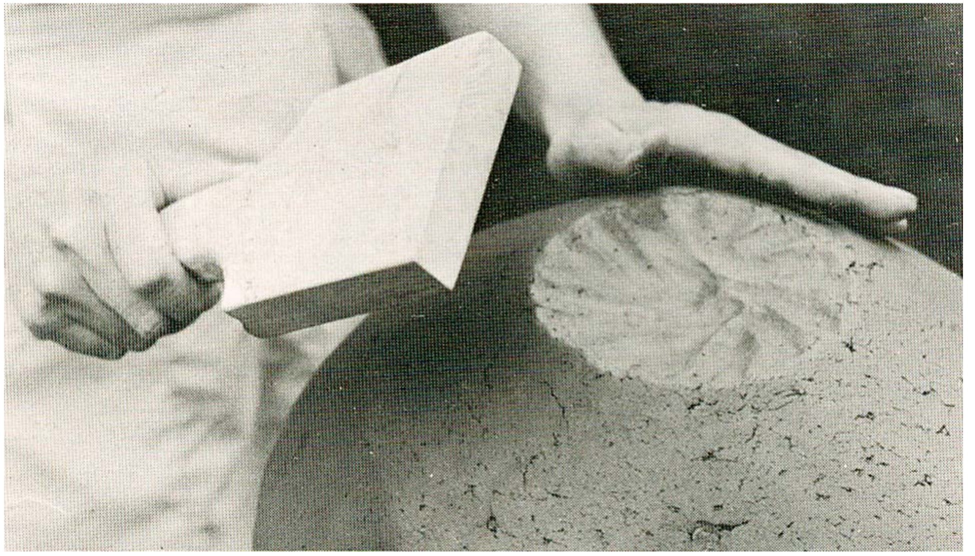
Spout will straighten out during firing

- Particle alignment during throwing may cause continued twist during drying and firing
  - Up to a 30º twist

•Twist continues in the direction of the spiral created by your fingertips

•Compensate by offsetting angle of attachment

Paddling

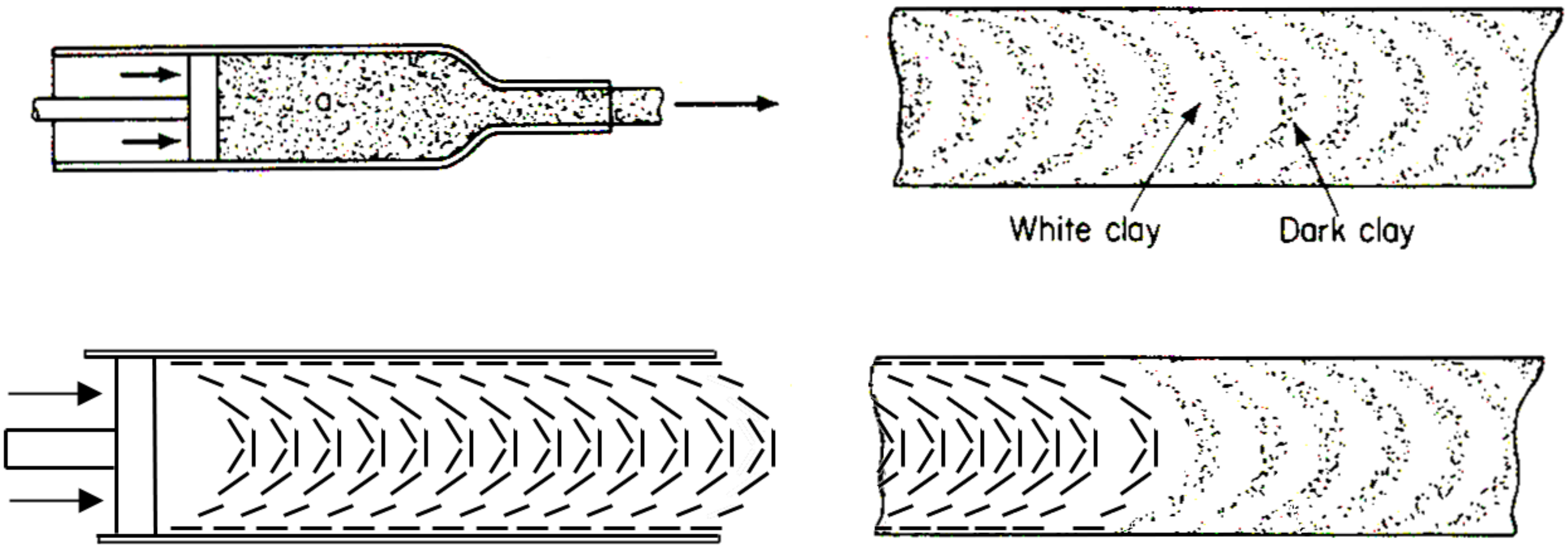


- Compresses / re-aligns particles
  - Greater contact/greater potential for extension
  - Increased workability
- Can help concentrate compression in very specific areas (I.e. along a seam)

Paddling

- Often used in conjunction with an anvil on the inside of the wall (as something to push against)

Extrusion

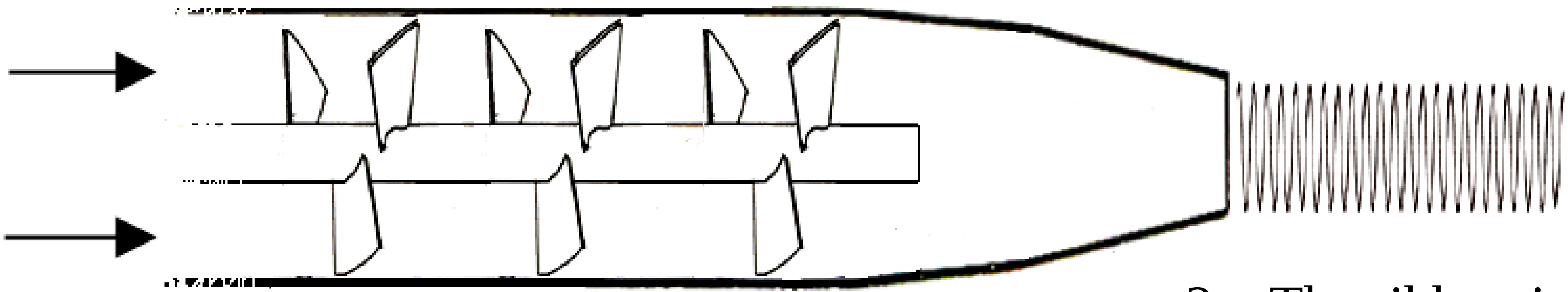


- Friction along the sides of the extruder
  - Flow rate decreases at the cylinder walls (due to friction)
  - Particles orient parallel to cylinder walls at the cylinder walls
  - This creates a dense outer skin on the extrusion’s outer walls

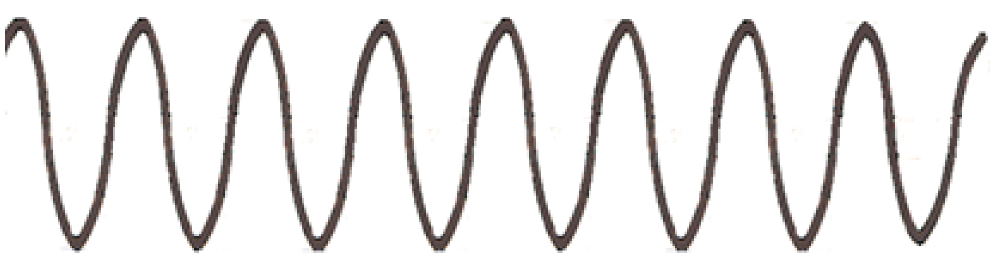
Lamination

- Occurs when two separate surfaces are joined
- Most processes we use involve laminating clay:
  - Wedging
  - Kneading
  - Pugging / hollow extruding
  - Coil building
  - Scoring and joining pieces

Lamination during pugging

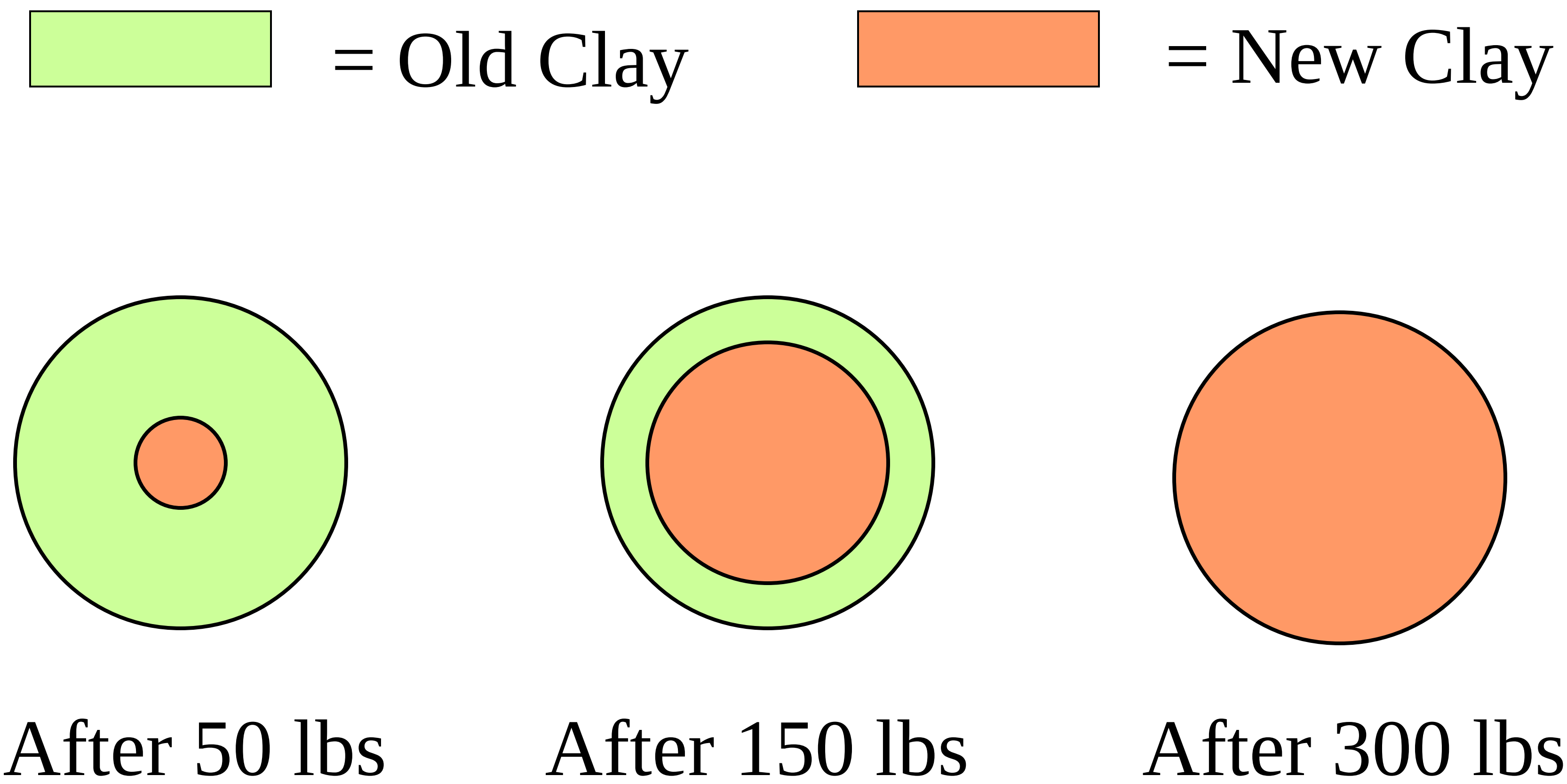


2 – The ribbon is laminated under pressure



1 - Clay is cut into a continuous ribbon by the auger blades

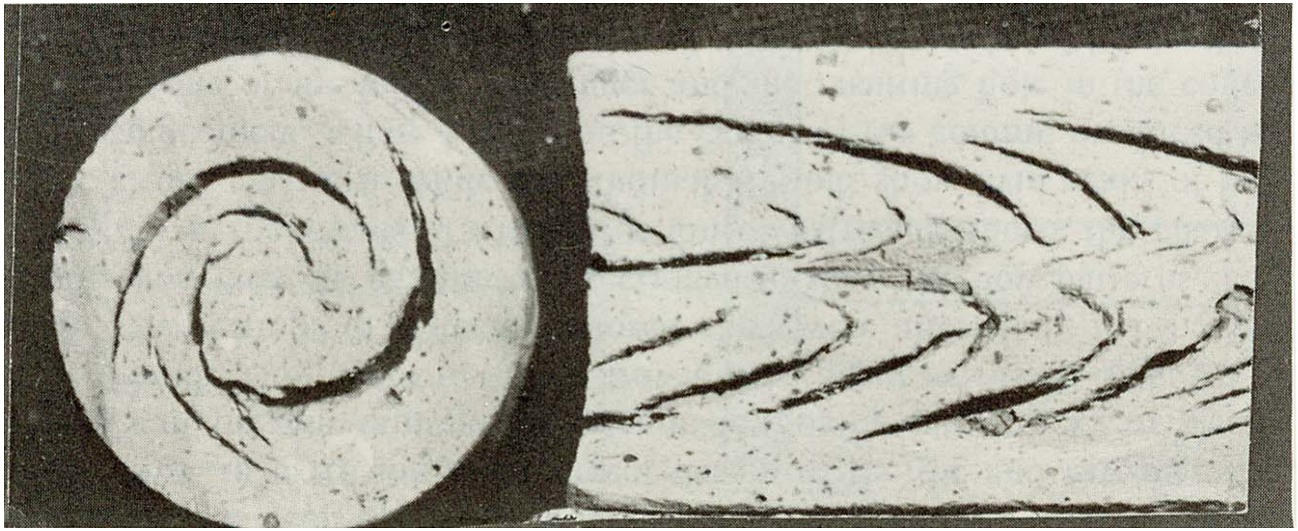
New clay in the pugmill starts at the center and eventually works its way to the edges



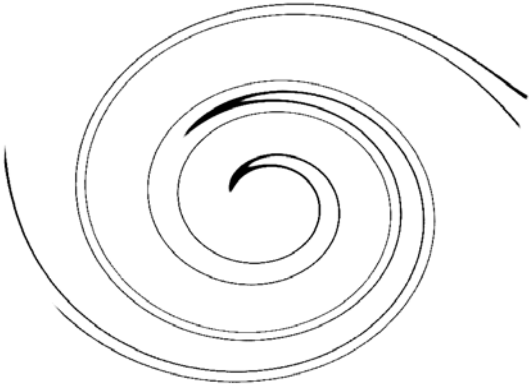
- A pug cut lengthwise reveals lamination (visible because of differences in clay body colors)
- Darker center is new clay that has been introduced into the machine

Delamination

- A weak plane in the body caused during the forming process which breaks open during drying or firing

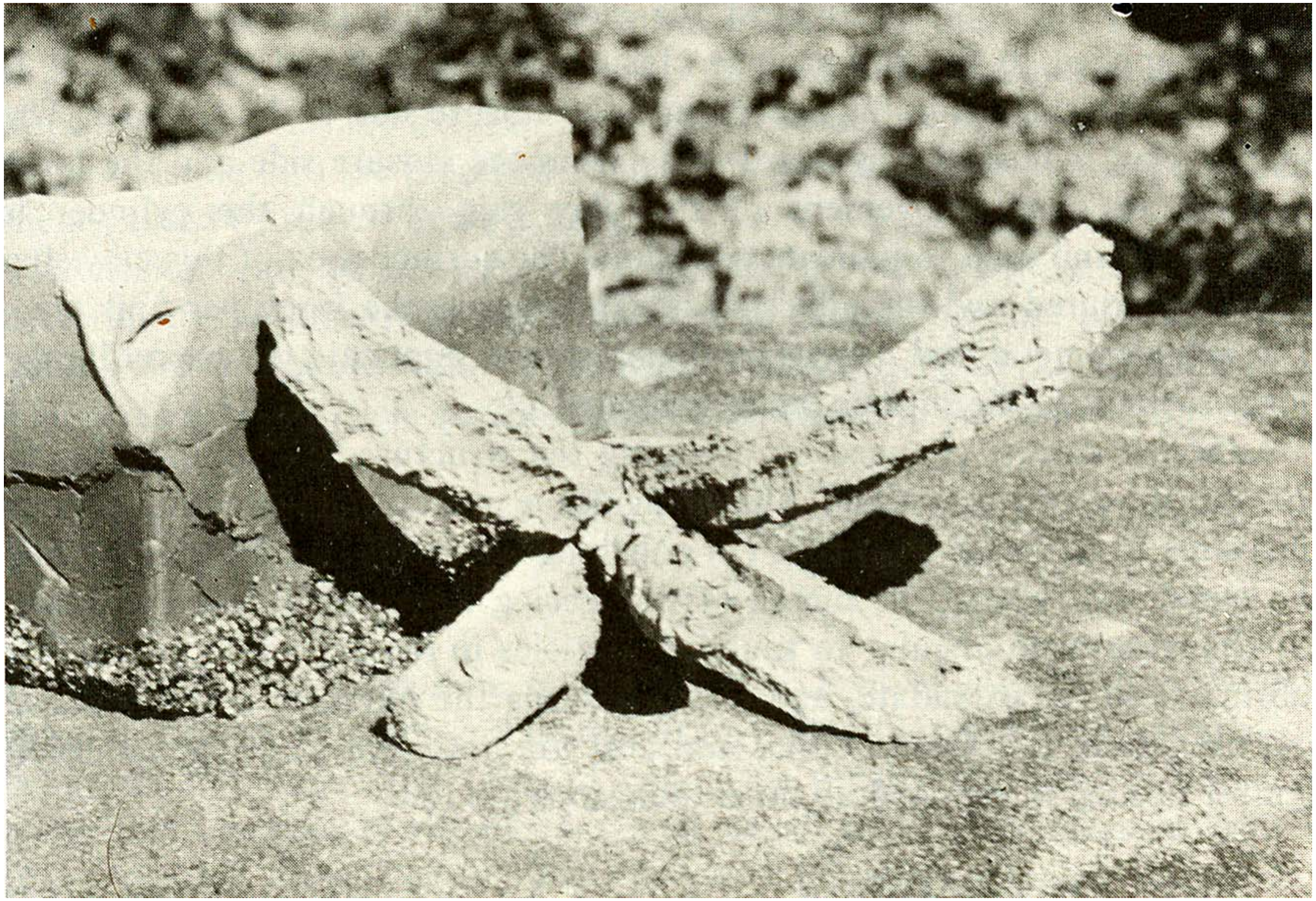


Pugged mass



Kneaded mass

Delamination



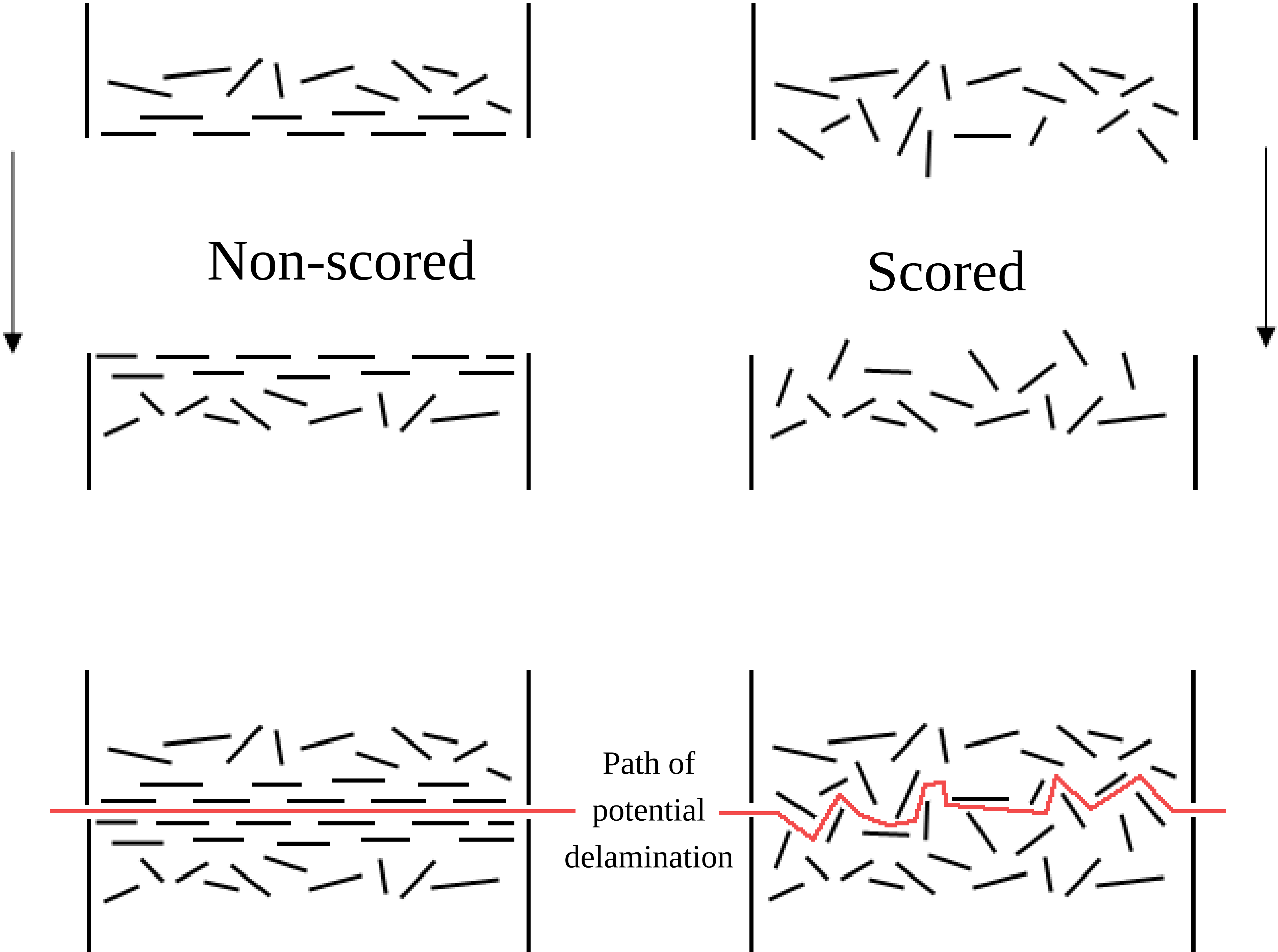
Pugged mass has distinctly different particle orientation (and compression) between inside and outside

Delamination in general

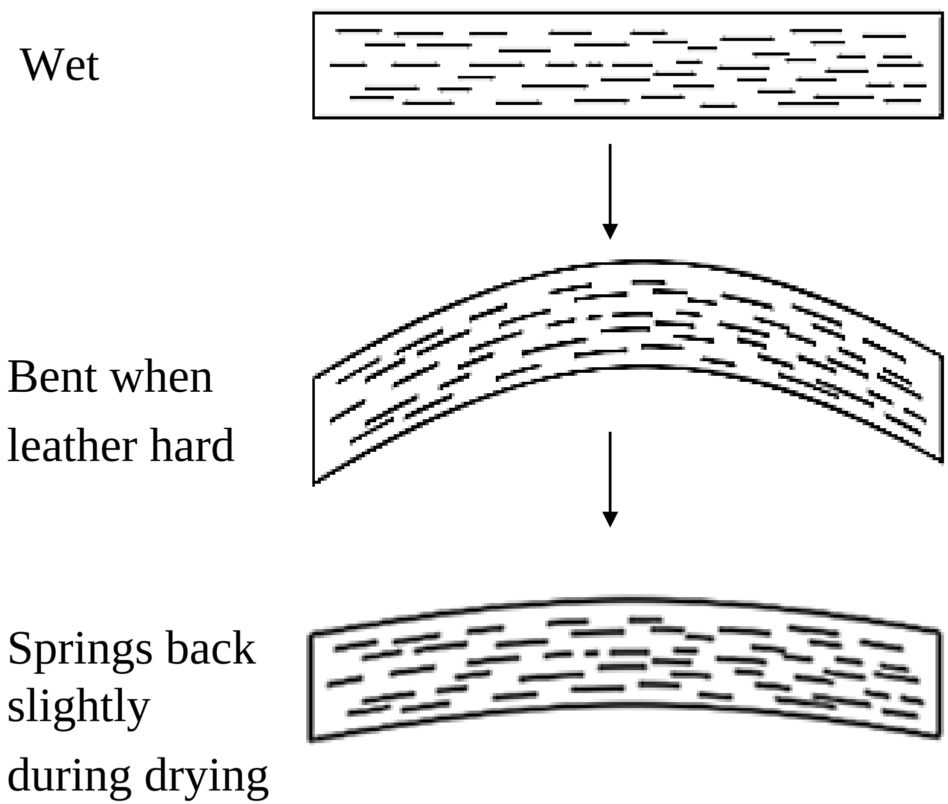
- Often caused by extreme differences in water content
  - too much or not enough water on joined surfaces
- May be caused by not enough clay in the body (too much grog; especially apparent when pugging)
- Extreme differences in particle orientation of separate faces
  - I.e. Joining without scoring

Scoring

- Acts like a primer, providing grip between otherwise smooth surfaces
  - Ideally you are creating many small undercuts
- Reduces delamination
  - Scoring randomizes particles
    - Particles are more likely to interlace, creating one continuous mass
    - Especially important when joining large flat areas together


Non-scored
Scored
Path of
potential
delamination

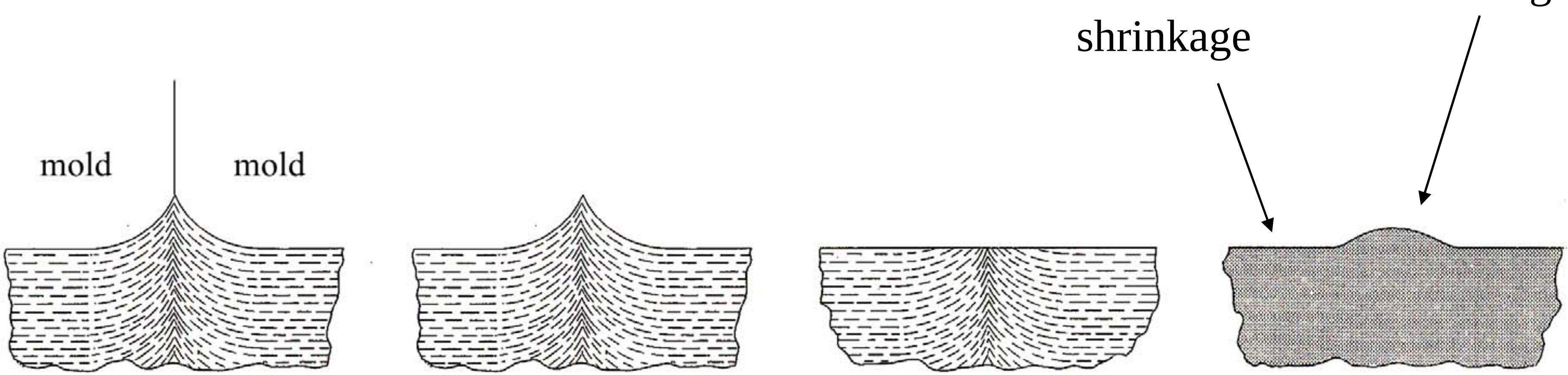
Memory During Forming



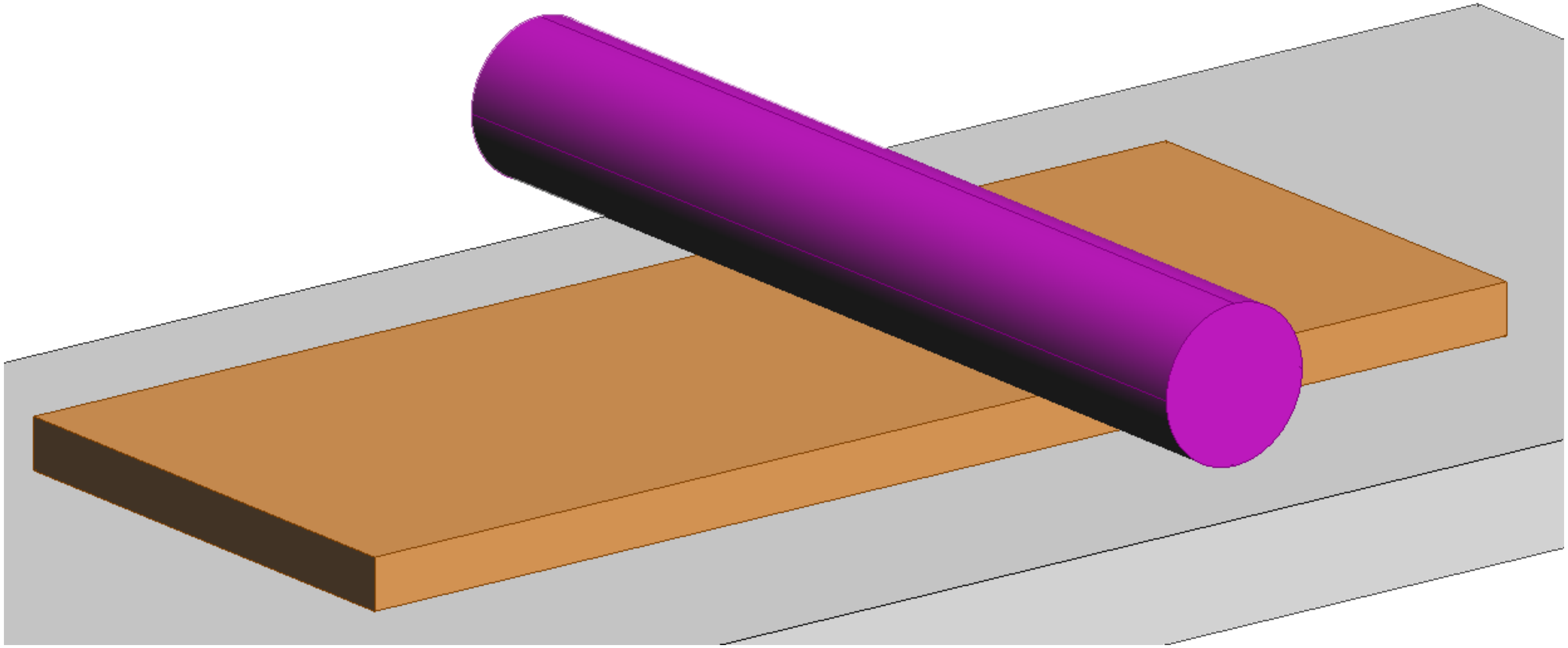
- Causes are not completely understood
  - Water content seems to affect memory retention
    - Bending a slab that is drier shows greater memory than bending a slab that is wetter
    - Bend shapes as early as possible to avoid memory effects
  - Memory is not time dependent (unaffected by speed of drying)

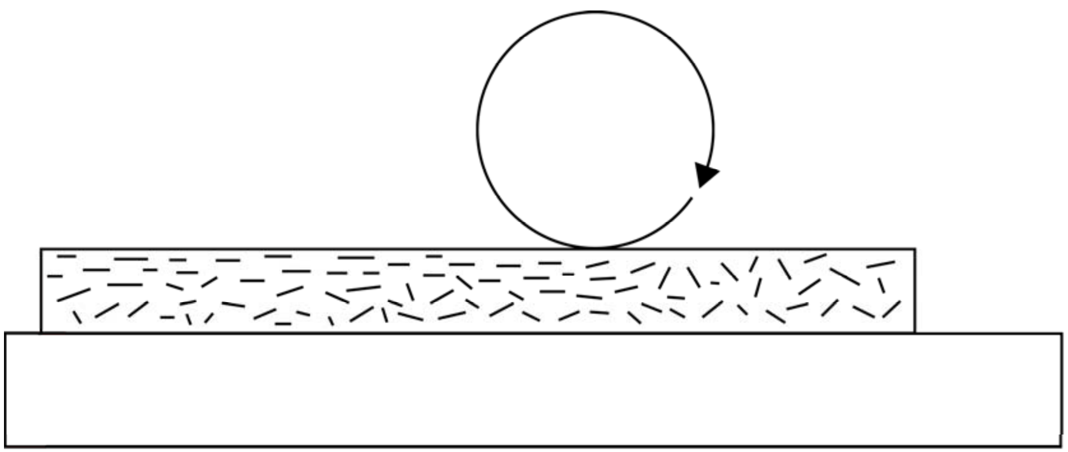
Memory of a seam in slipcasting during drying and firing

- Compacted areas at seams exhibit differential shrinkage
- Even after fettling flat, these areas appear raised after firing

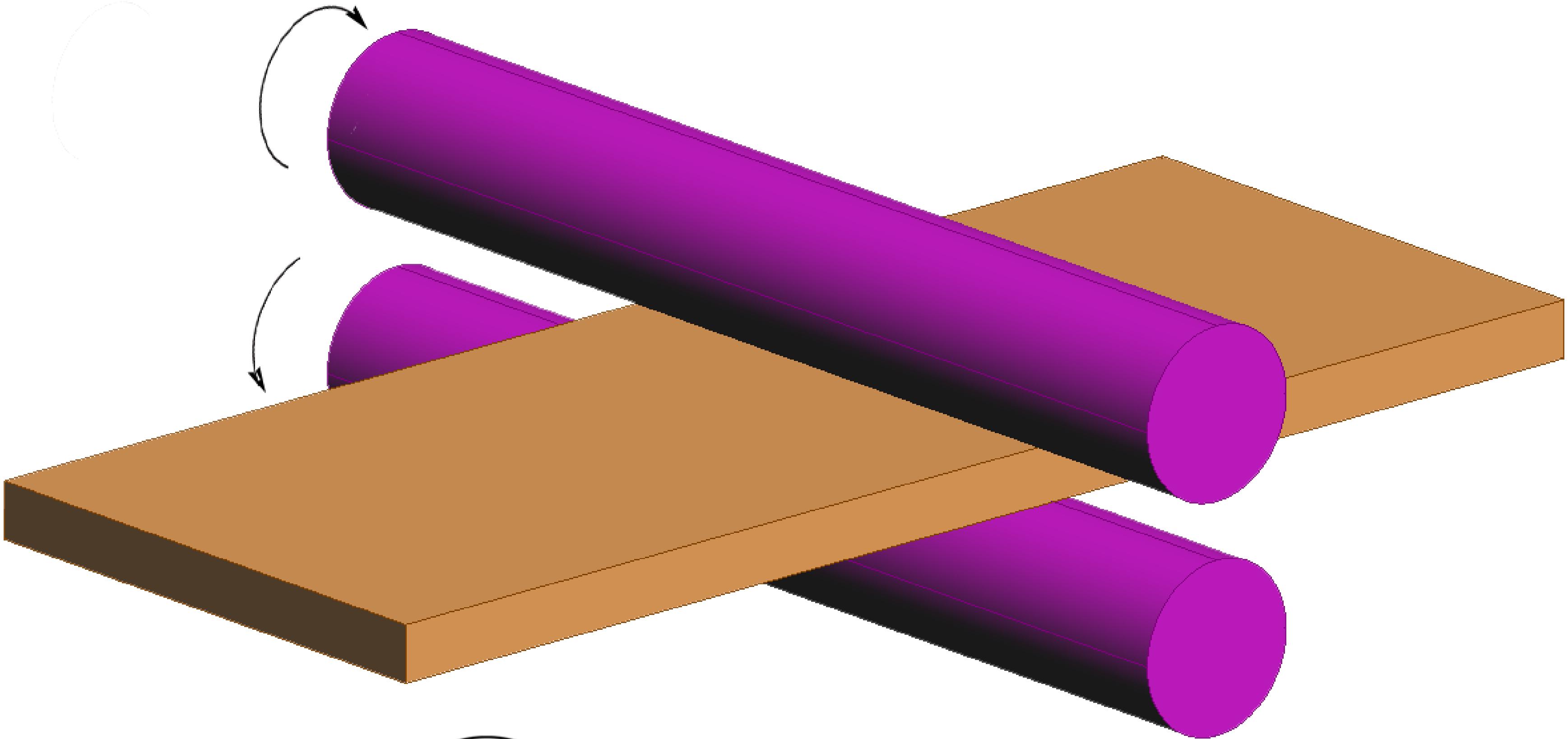


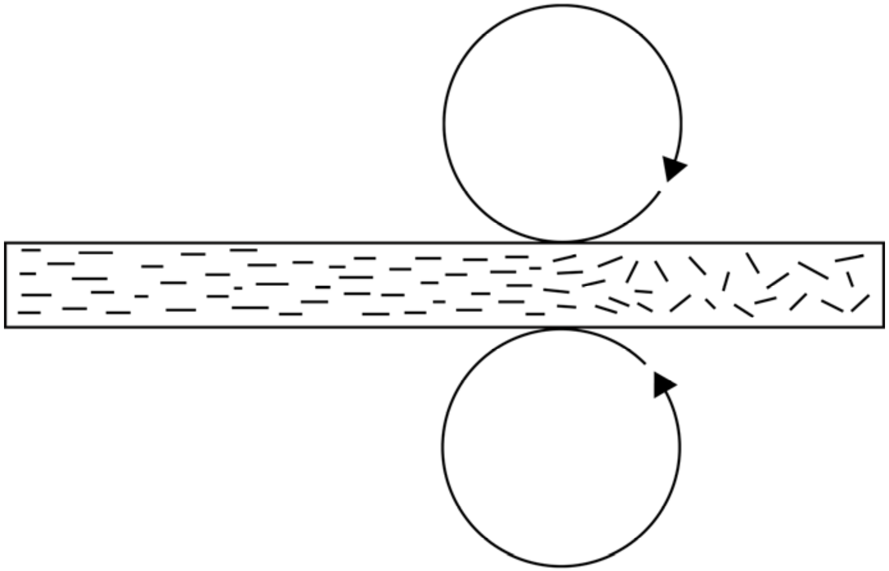
- Memory of a seam can be compensated for
  - Remove original material along the seam
  - Score seam to randomize alignment and destroy memory
  - Fill with separately rolled coil
  - Hammer coil and surrounding surface to realign particles parallel to surface





- Slab Roller
  - Alignment/Compression primarily on one surface only
  - Slab must be flipped and re-rolled to equalize particle alignment on both sides

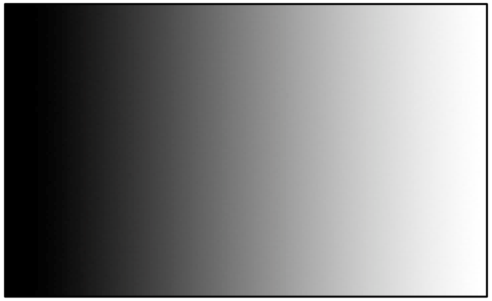




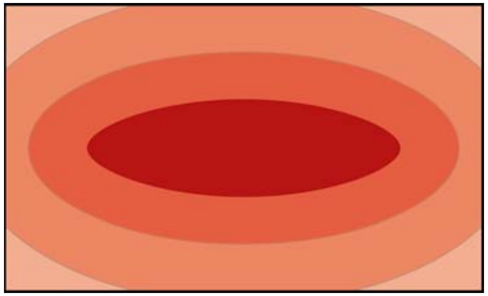
- Roll compaction
  - Extensive use in industry
  - Equal alignment/compression on both sides
  - Some studio slab rollers use this principle

Preface to the density gradient theory

- Although we have looked at diagrams representing a clay body as many small plates, in reality there are many other materials present in a clay body
  - Flint, Fluxes, Fillers, etc.
  - These other materials are not flat, and are much larger than the clay plates
    - These non-clay materials minimize the effects of clay orientation
    - The more non-clay materials we add to our body, the less “particle orientation” is a factor and the more “density gradients” play a larger role



Examples of Gradients



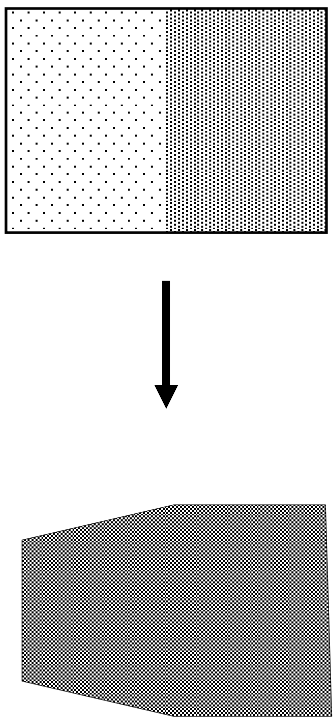
Density gradients

- After forming, some areas are denser than others
  - due to compression and stretching during forming
- After firing, bodies will always have the same density throughout
  - Less dense areas have to shrink more to catch up to denser areas
- “catching up” results in more shrinkage of particles in less dense areas
  - Leads to varying amounts of tension and compression in the same piece

Density differences before firing

Less dense

More dense



Equal density after firing

Stress

(A force exerted by one body on another)

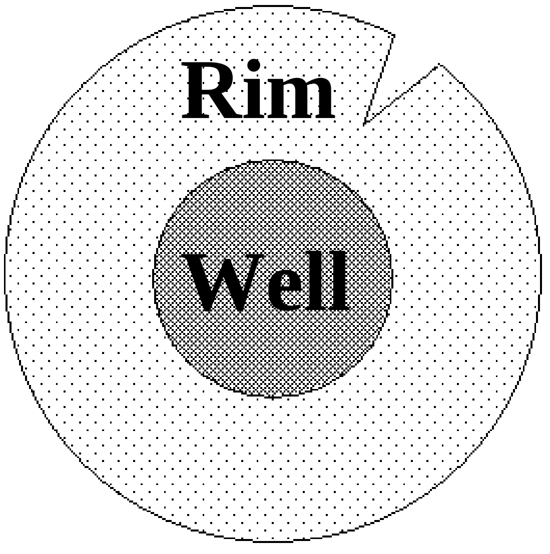
Tension and compression

Cracking is due to tension

Tension
(pulling apart)

Warping is due to compression

Compression
(pushing together)

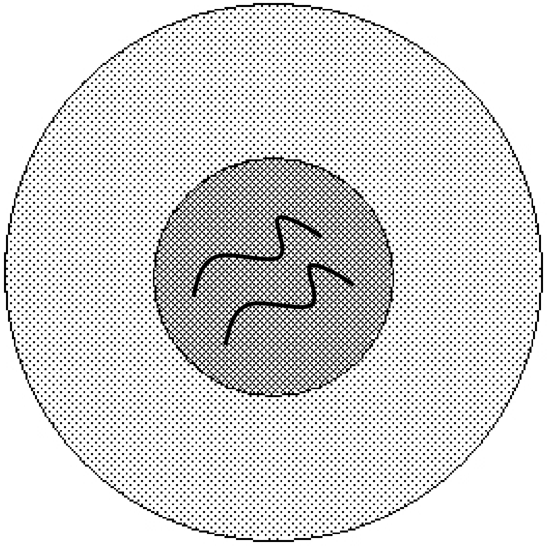


Well is <u>much</u> denser than rim

= Rim Cracking

As the rim densifies during firing, it undergoes severe tension

It pulls away from itself, forming a crack



Well is denser than rim

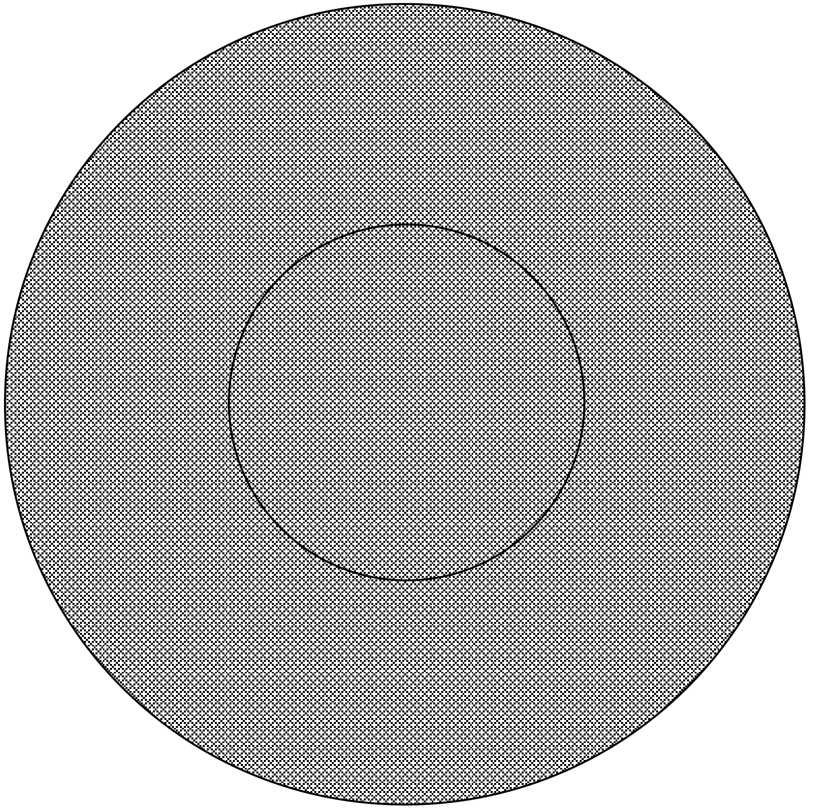
Well warps (drops)

(AKA: spinner)

Rim is in tension, but not enough to crack

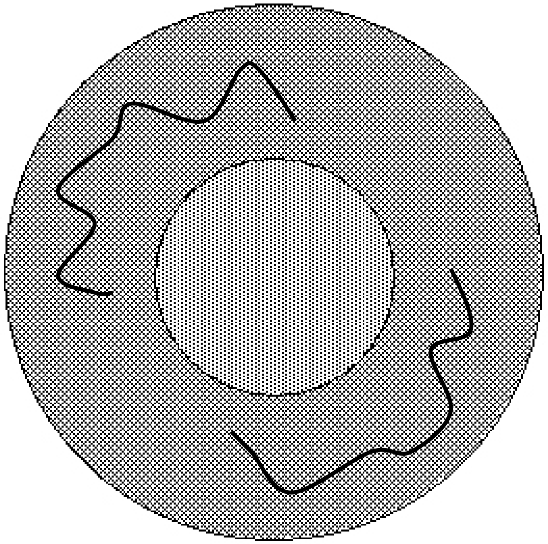
Well is in compression

The center buckles downward with the help of gravity



Both rim and well are equally dense

Flat, crack-free

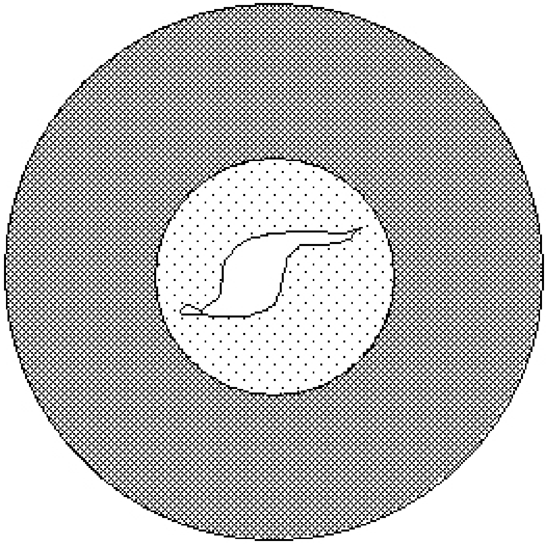


Rim is denser than well

= Rim Warping

Well is in tension, but not enough to cause a crack

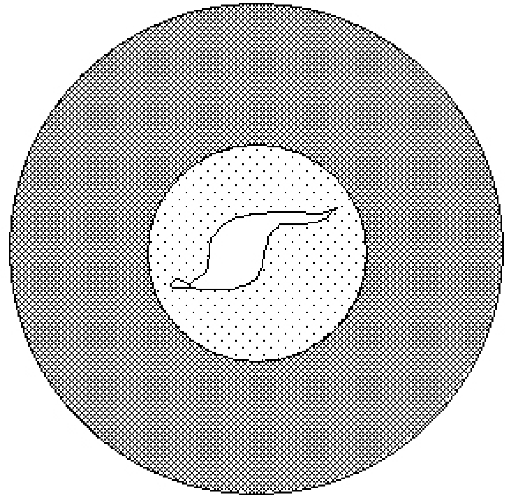
Rim warps because it is in compression



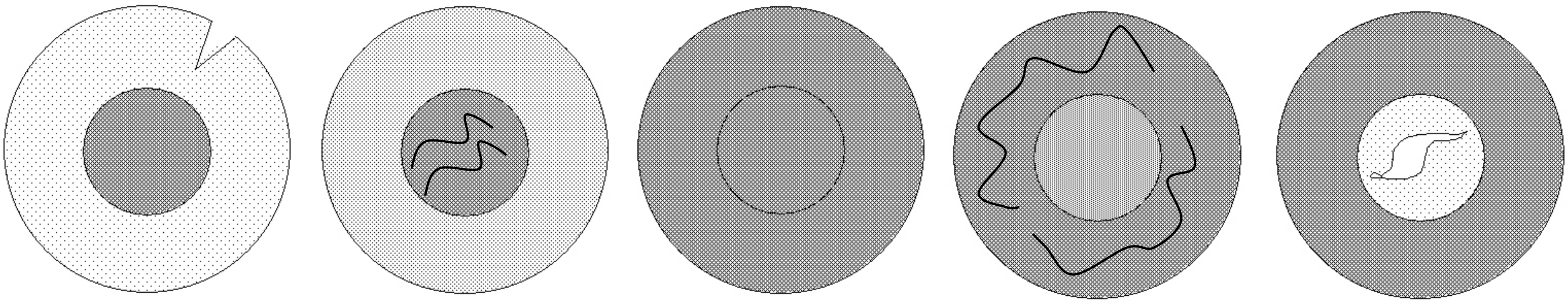
Rim is much denser than well

= Well Cracking

Well is in severe tension and cracks



- Less than 10% difference between rim and well densities can lead to cracking
- When cracking occurs, there is usually no warpage
  - Stress is relieved
- Excess water in the well leads to a density difference, even if both rim and well are equally compressed during forming
  - Excess water in the well permeates the body which leads to a decrease in clay density.



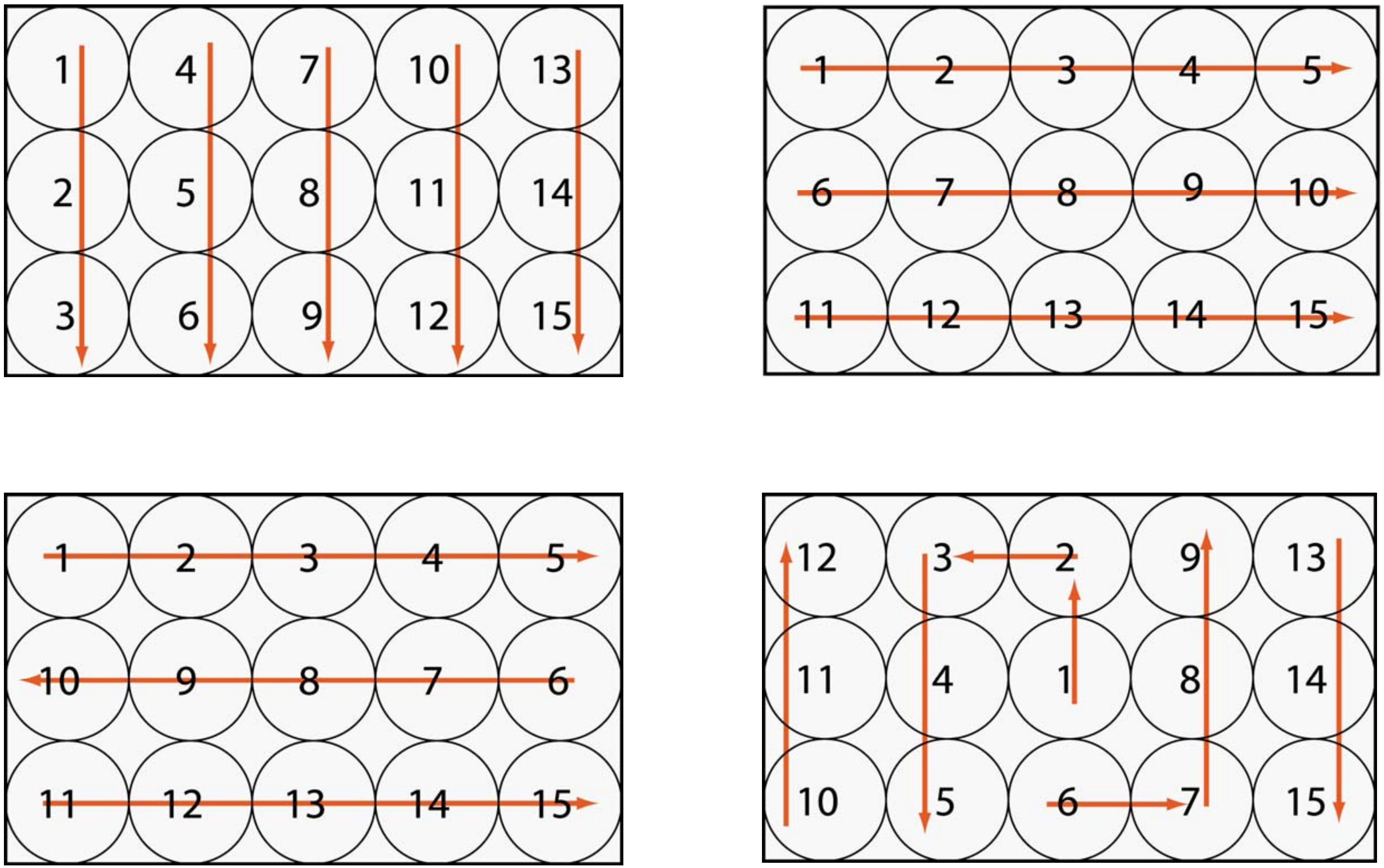
Crack Warp Good Warp Crack

So…

- Warpage and cracking often result because of density gradients created during forming
- Decreasing these gradients (by equalizing density during forming) minimizes warpage and cracking during firing

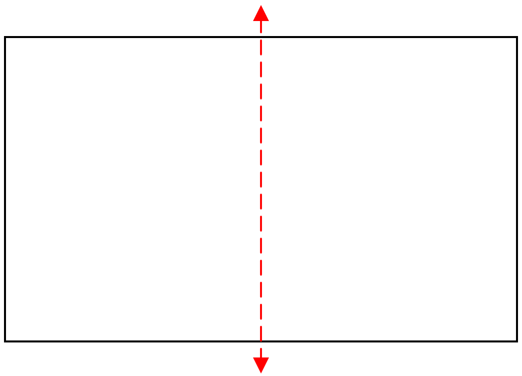
Given what we know about warping in relation to density gradients, how can we make flat slabs?

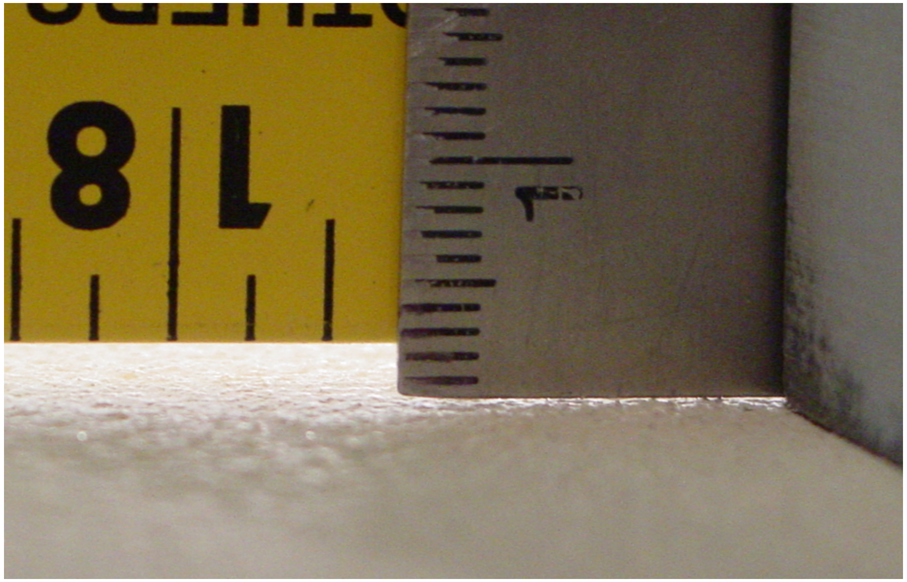
Possible compression patterns for pounding out a slab



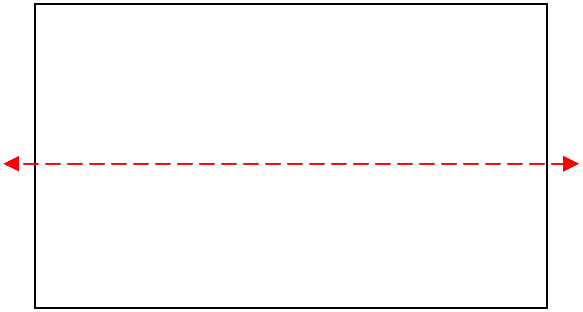
Is one pattern more effective than another in reducing density gradients during forming?

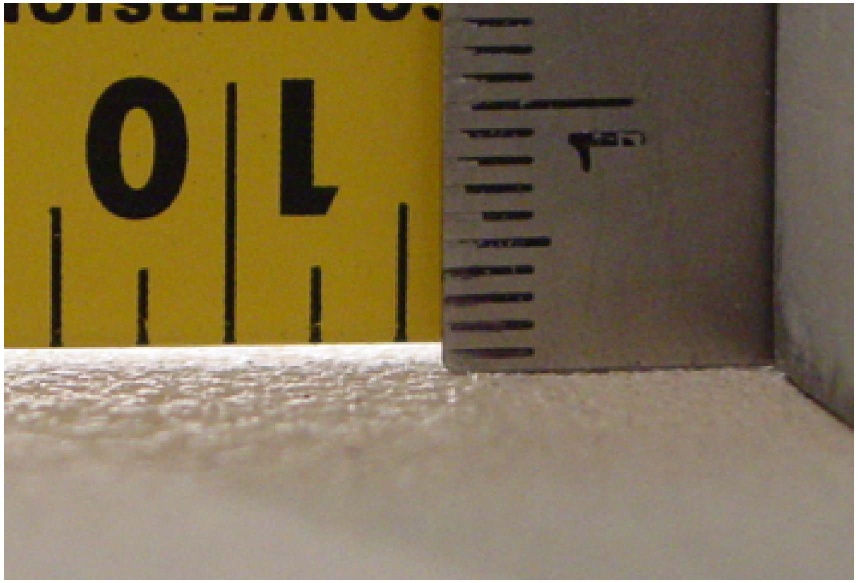
Dry slab was sanded perfectly flat on both sides using sandblasted glass plate





- Post-fired warpage = 3 mm

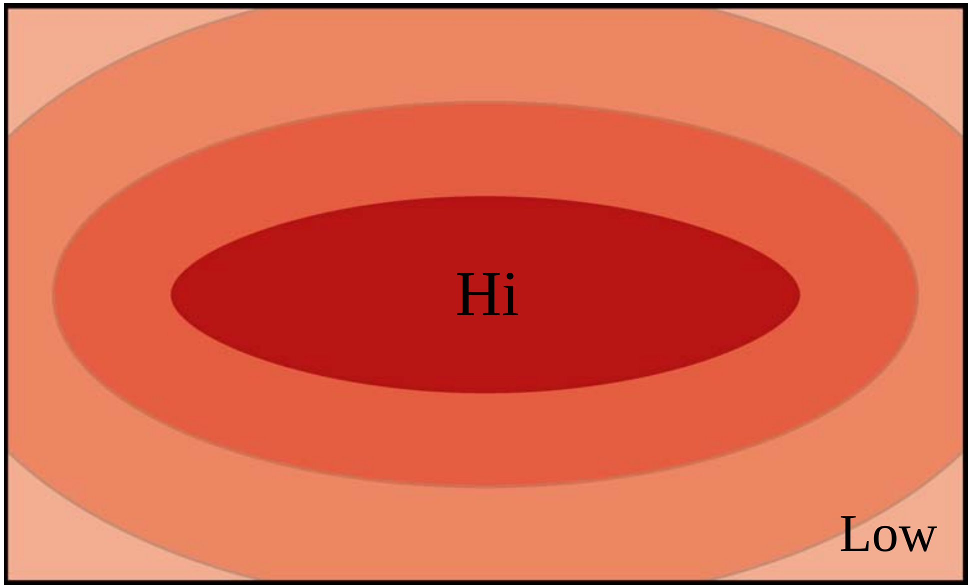




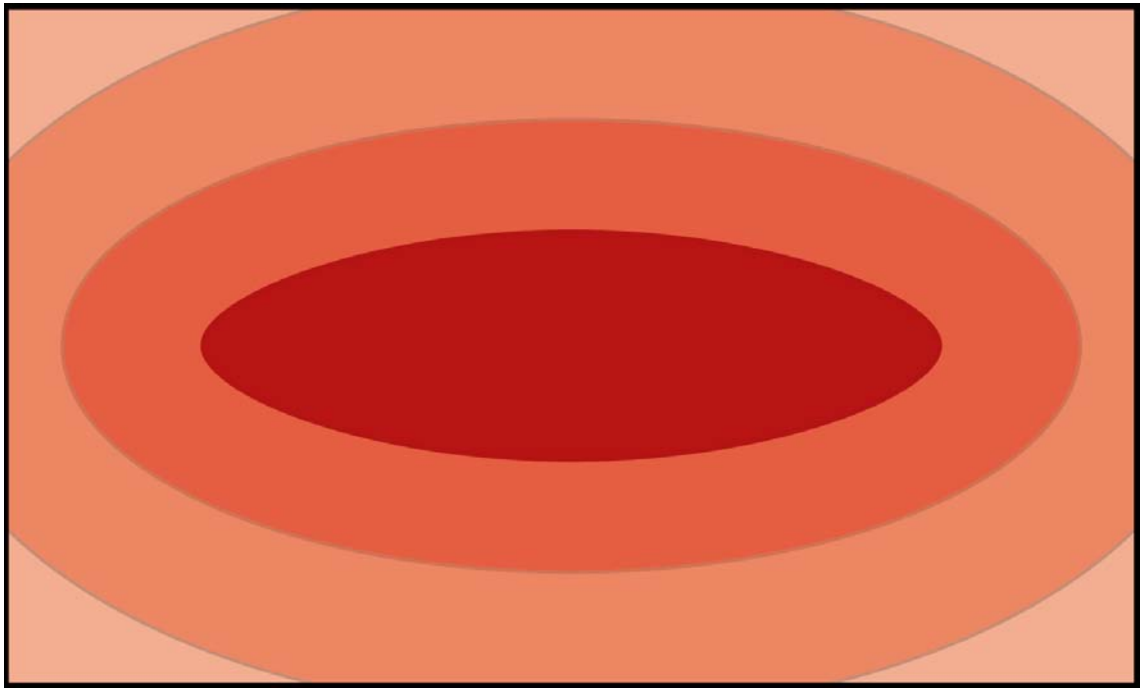
- Post-fired warpage = 1.5 mm

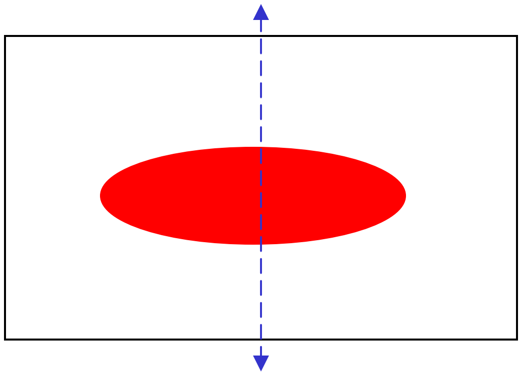
Density gradients are inevitable

A gradient occurs regardless of the compression pattern used



- Clay at the center is restricted in movement during forming (is compressed) by the clay at the edges
- Clay at the edges can freely move outwards during forming (is less compressed)

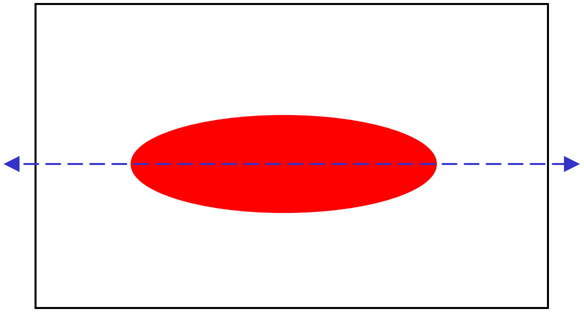




Smaller area of compression relative to the overall length in this direction

Greater density gradient

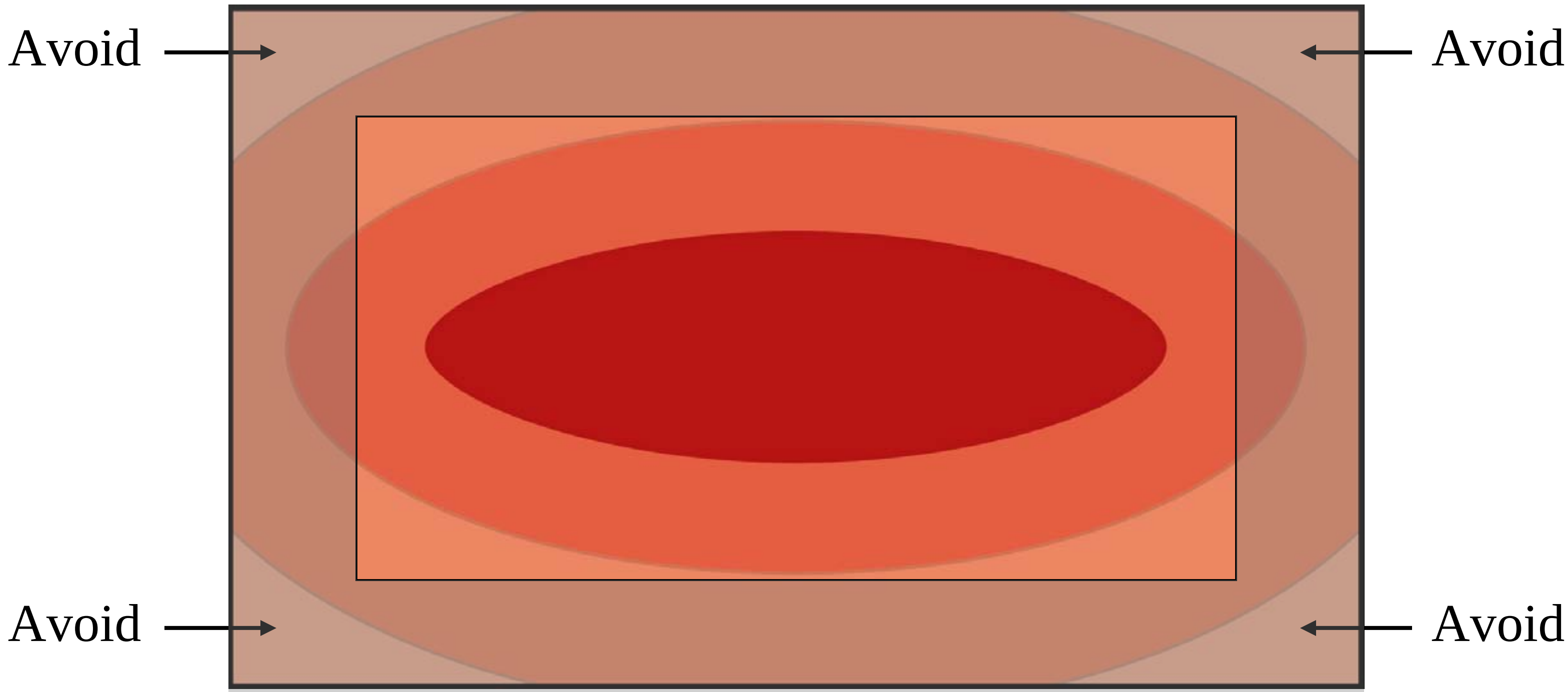
3 mm of warpage



Larger area of compression relative to the overall length in this direction

Smaller density gradient

1.5 mm of warpage



- When building from slabs, avoid using material at the edges (I.e. make your slabs larger than needed, and discard the excess)

What is the best way to make a really FLAT slab?

Stay tuned to find out!...

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