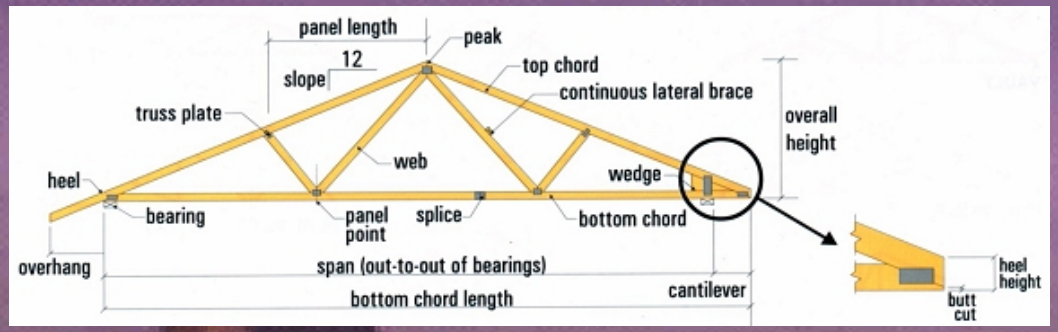
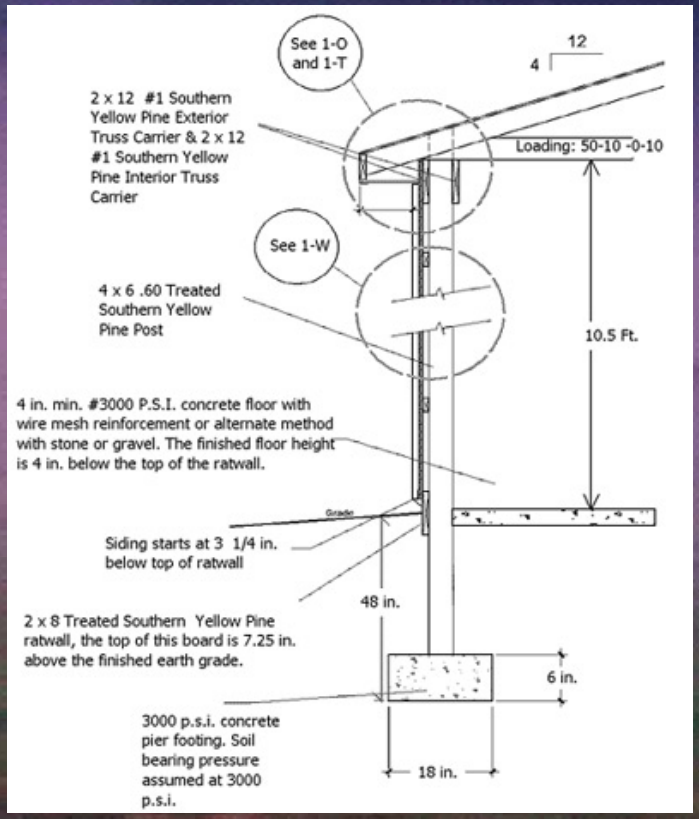
Hay storage structures





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Barns for Bales

Site selection

- Drainage
- Access
- Building separation and expansion
- Other

Drainage

- Do not build in a hole or on steeply sloped sites
- Keep rain and melt water away from barn and surrounding area
- Slope surrounding ground away from walls (at least 2% = 2-ft vertical per 100-ft horizontal)
- Divert runoff from multiple adjacent areas

Access

- Plan for convenient access:
  - You may need to compromise between:
    - Road access
    - Security from fire and theft
- Roadways and turning areas should allow ample space for trailers and bale wagons:
  - Plan to have an area of 75 x 125 ft for vehicle maneuvering
- Plan to accommodate heavy equipment

Building separation and expansion

- Spacing is often a compromise between safety and practicality
- Allow adequate space for future expansion
- Space buildings at least 75-ft apart to reduce the spread of fire
- Availability of water for fire fighting is desirable

Other considerations

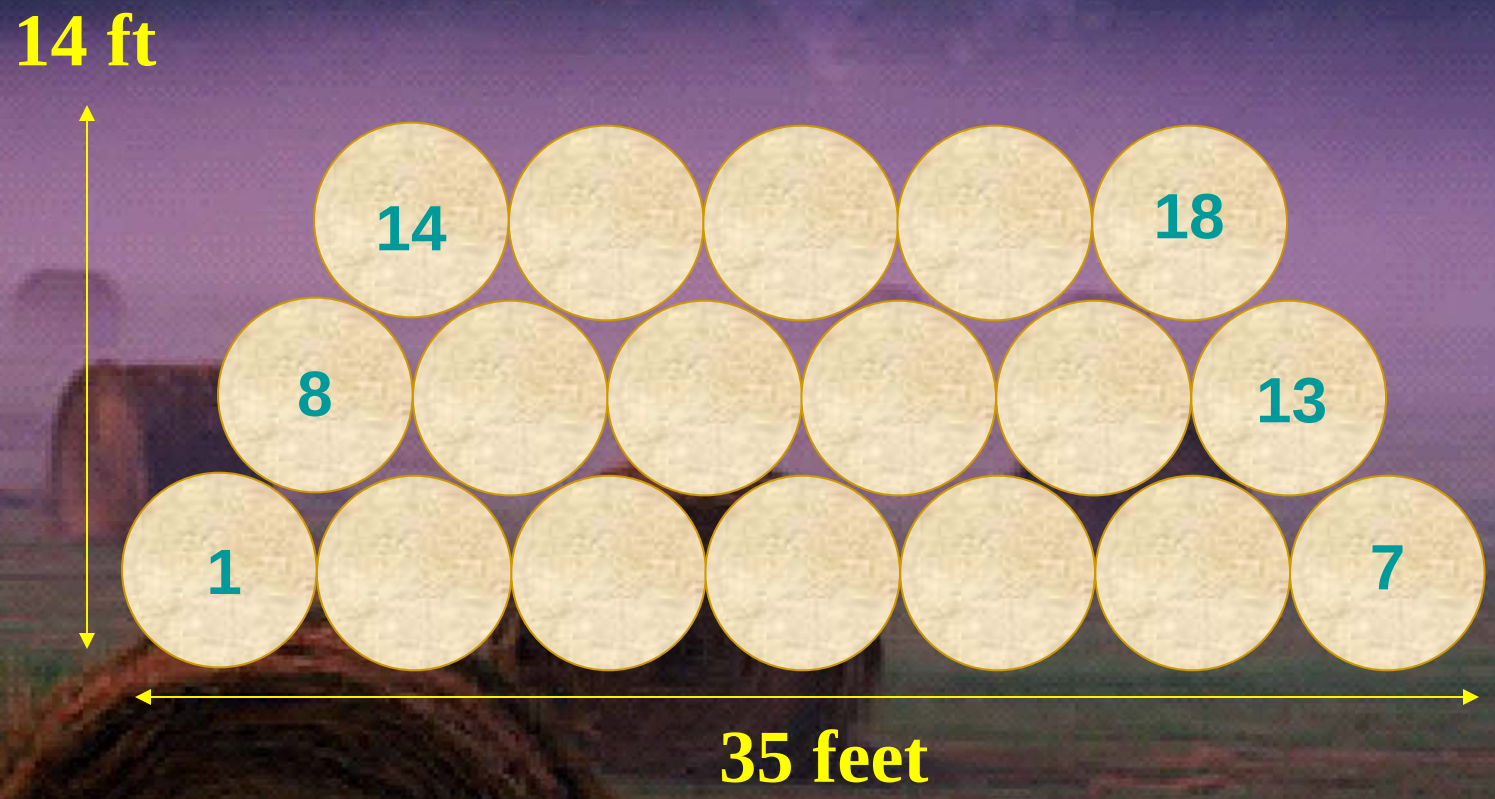
- Avoid sites with rock or rock outcroppings, otherwise you may need:
  - Special excavating equipment
  - Building anchorage
- Consider weather protection
  - Winter storms usually come from the NW or SW
  - Check your local conditions – prevailing winds
  - Open front building should face East
- Consider sun exposure
  - Sun will always be in the S and W sky during afternoon

Building space

- "Regular" density bales:
  - 10 to 12 lb/ft^3
- "High" density bales:
  - 15 to 20 lb/ft^3
- Allow 10 to 15 ft^2/ton for square bales
- Allow 16 to 24 ft^2/ton for round bales

Stack Height

5 ft. diameter bales

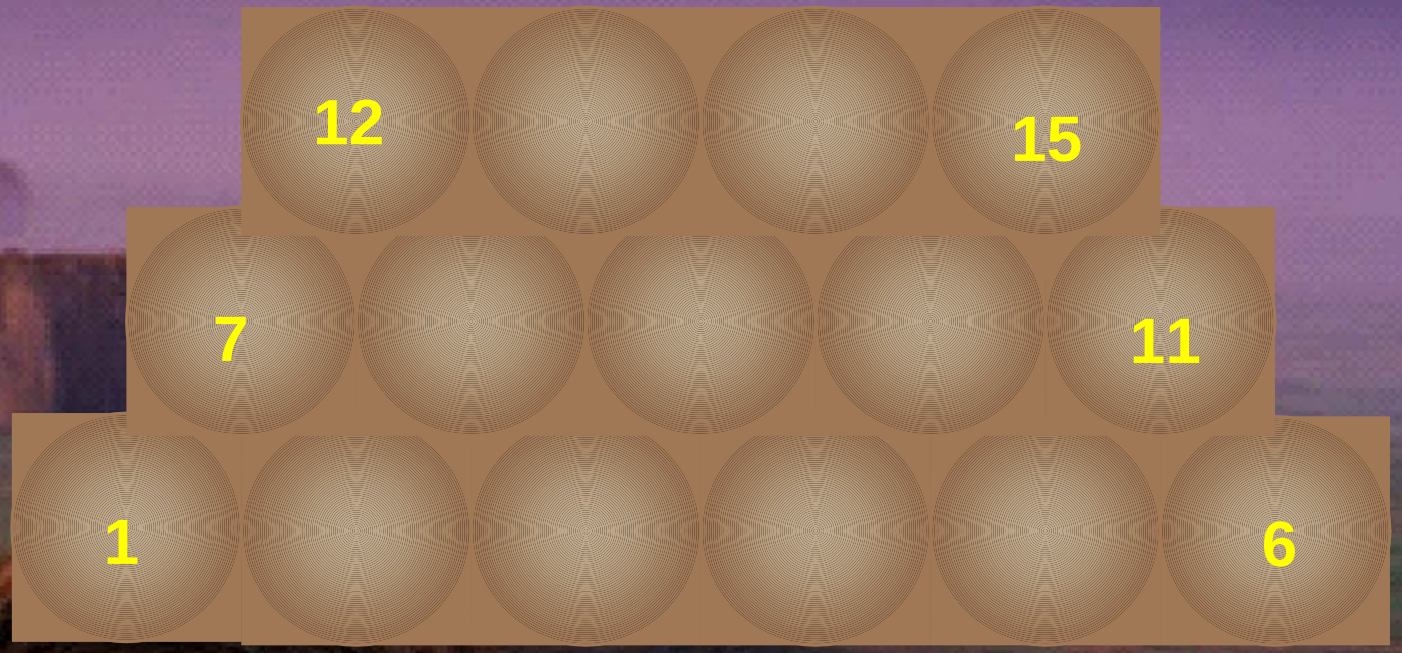


Stack Height + 2 feet = Floor to truss clearance

Stack Height

6 ft. diameter bales

16 ft – 9 in.



36 feet

Stack Height + 2 feet = Floor to truss clearance

Capacity – Vertical Stack

Building size (ft)	5-ft diam x 5-ft		6-ft diam x 5-ft	
	2 high	3 high	2 high	3 high
26 x 64	110	165	88	132
32 x 64	132	198	110	165
36 x 64	154	231		
38 x 64			132	198
42 x 64	176	264		
44 x 64			154	231
46 x 64	198	297		
50 x 64			176	264

Source: Oklahoma State University Extension Facts F-1716

Capacity – Pyramid Stack

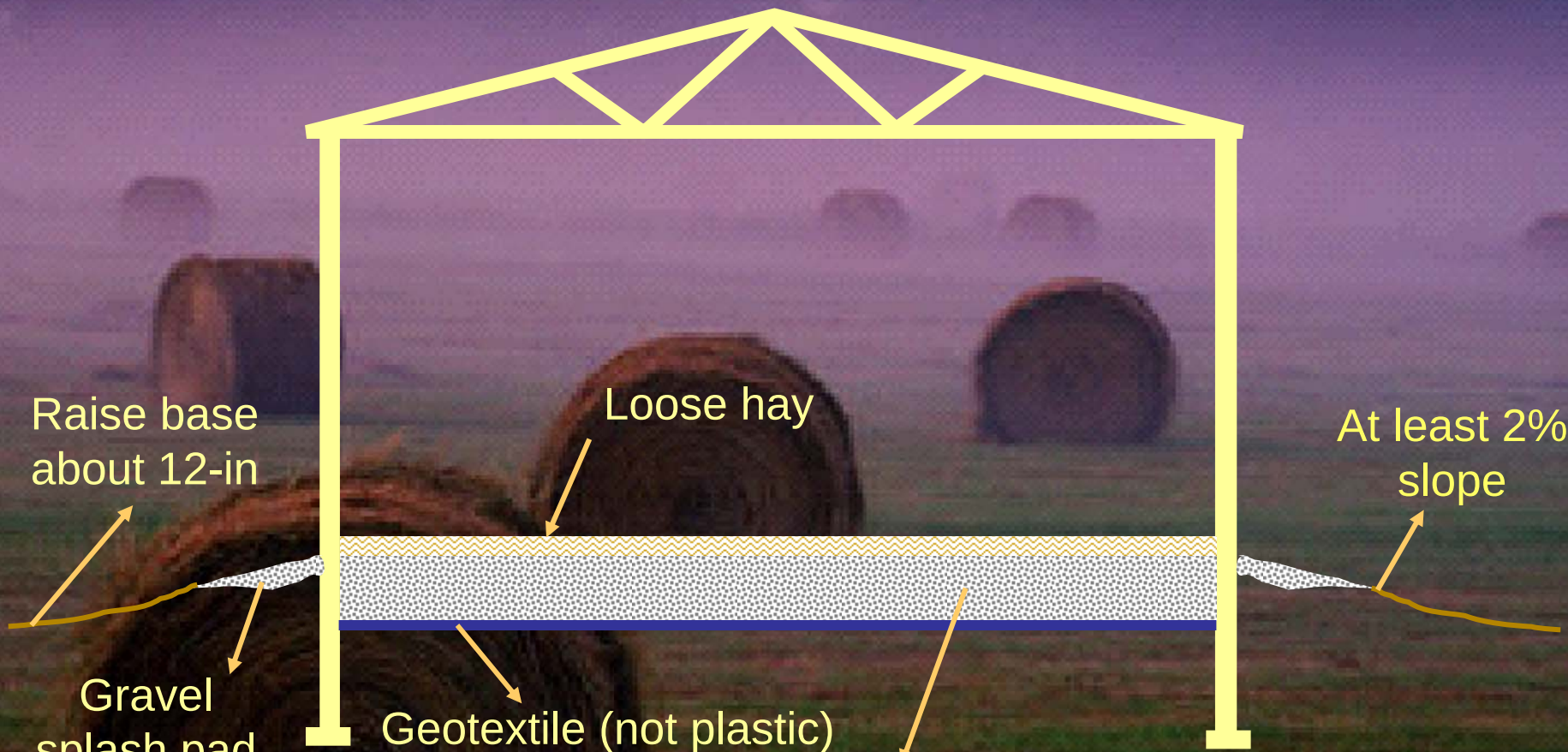
Building size (ft)	5-ft diam x 5-ft		6-ft diam x 5-ft	
	2 high	3 high	2 high	3 high
26 x 64	99	132	77	99
32 x 64	121	165	99	132
36 x 64	143	198		
38 x 64			121	165
42 x 64	165	231		
44 x 64			143	198
46 x 64	187	264		
50 x 64			165	231

Source: Oklahoma State University Extension Facts F-1716

Floor and base

- Compacted gravel – use large rocks
- Geotextile with compacted gravel
- Compacted gravel with shipping pallets, rough boards or planks
- Coal combustion products – fly ash, FGD
- Concrete
- Layer of loose hay

Floor and base construction



Coal combustion products

- FGD material:
  - Dewatered mixture of sulfites and sulfates, lime, and some water
  - Self-cementing
  - Probably the best option among CCP
- Fly-ash:
  - Class C: self-cementing, not always available
  - Class F: not self cementing, but usually readily available
- These are NOT considered hazardous materials

Post – Frame Construction

Formerly known

as

“Pole Barns”

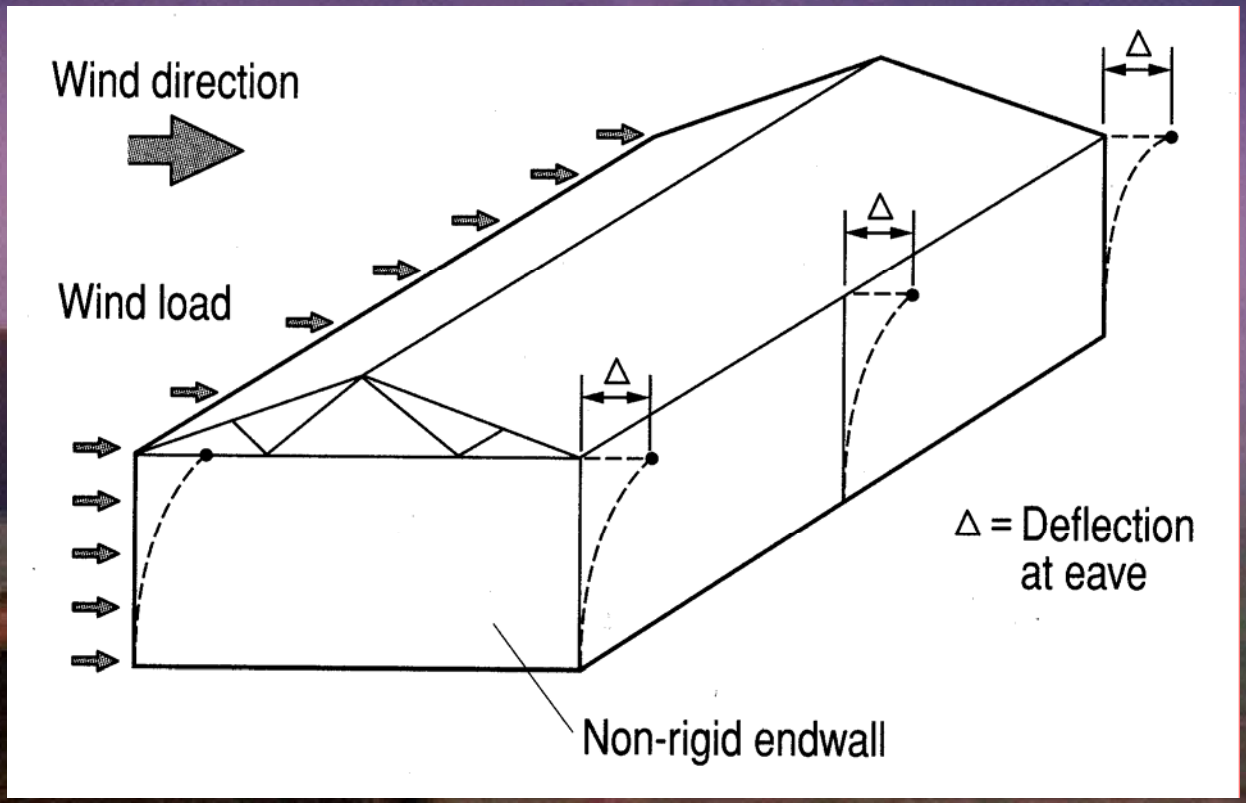
Structural loads

- Dead loads:
  - Gravity loads that are always present
  - Due to the combined weight of all permanent structural (ex: trusses, roof) and non-structural components of the building (ex: ventilation and heating equipment)
- Live loads:
  - Loads that are not fixed in place, or are applied intermittently
  - Caused by nature, people, animals, materials, and movable equipment

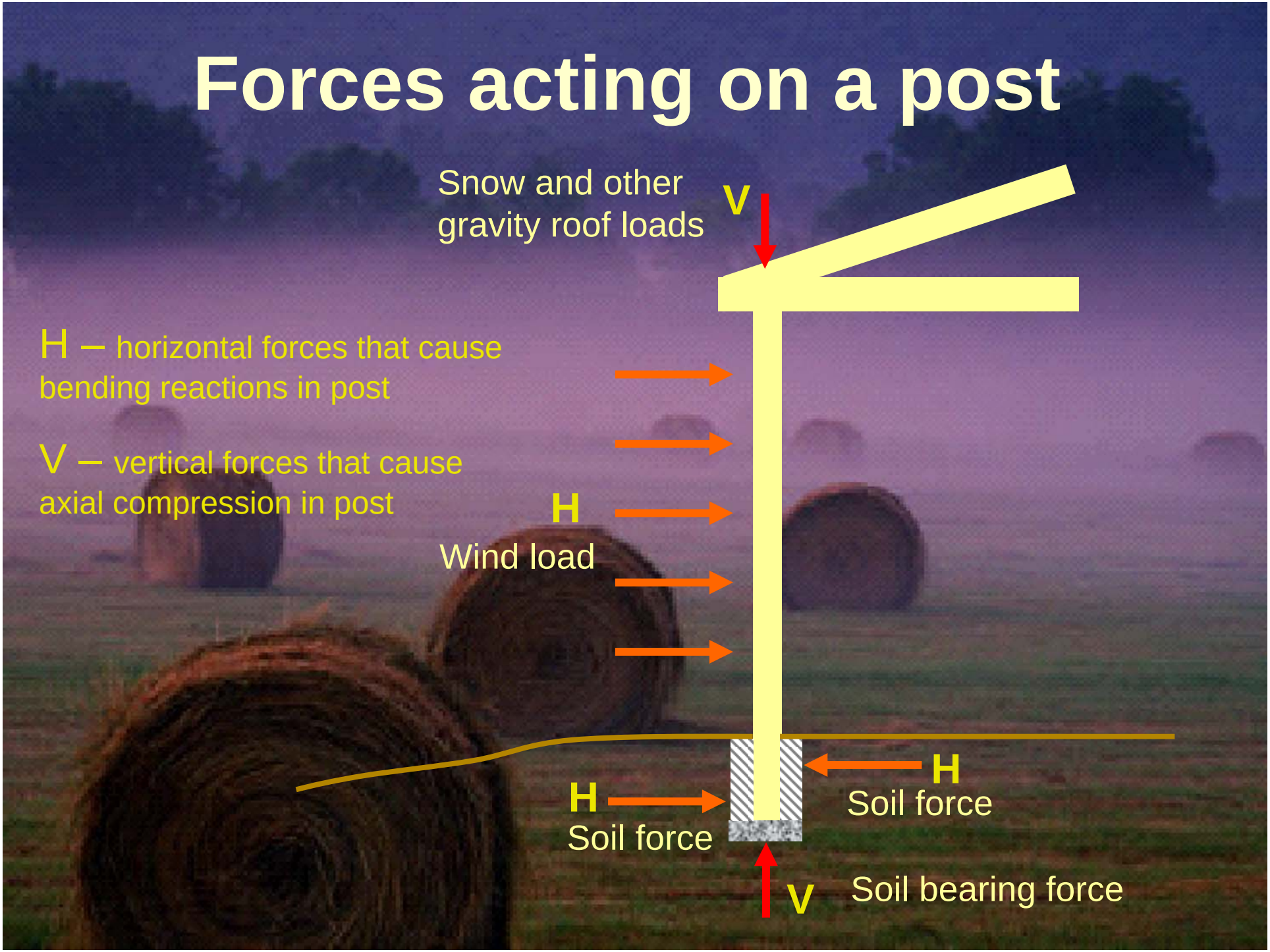
Selected floor live loads

Use	Floor load (lb/ft^2)
Calves up to 300 lbs	50
Cattle or horses	100
Hay or grain storage	300
Farm vehicle storage	100
Large tractors (>13,000 lbs)	200
Shops, maintenance	70

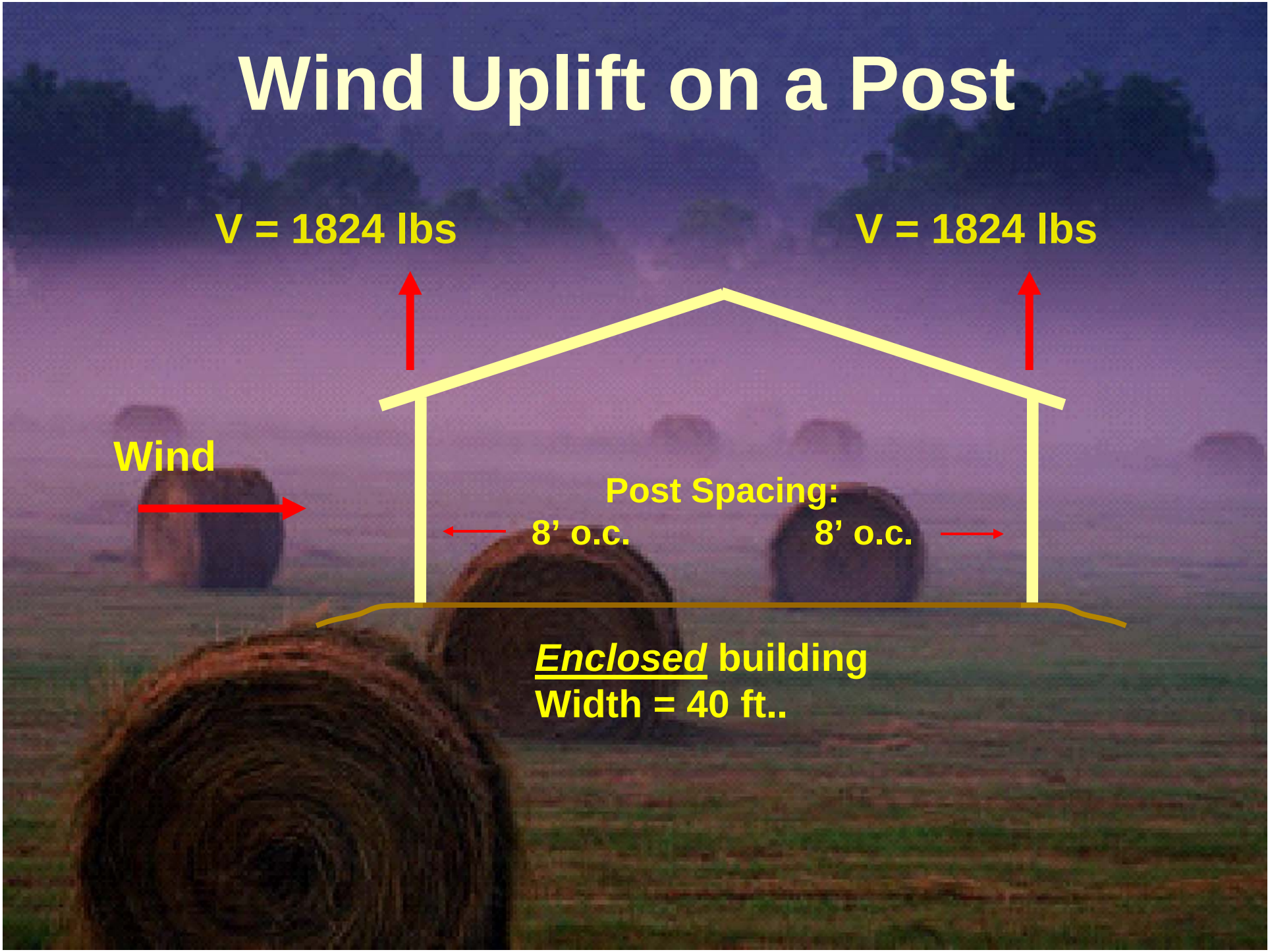
Post-Frame Construction



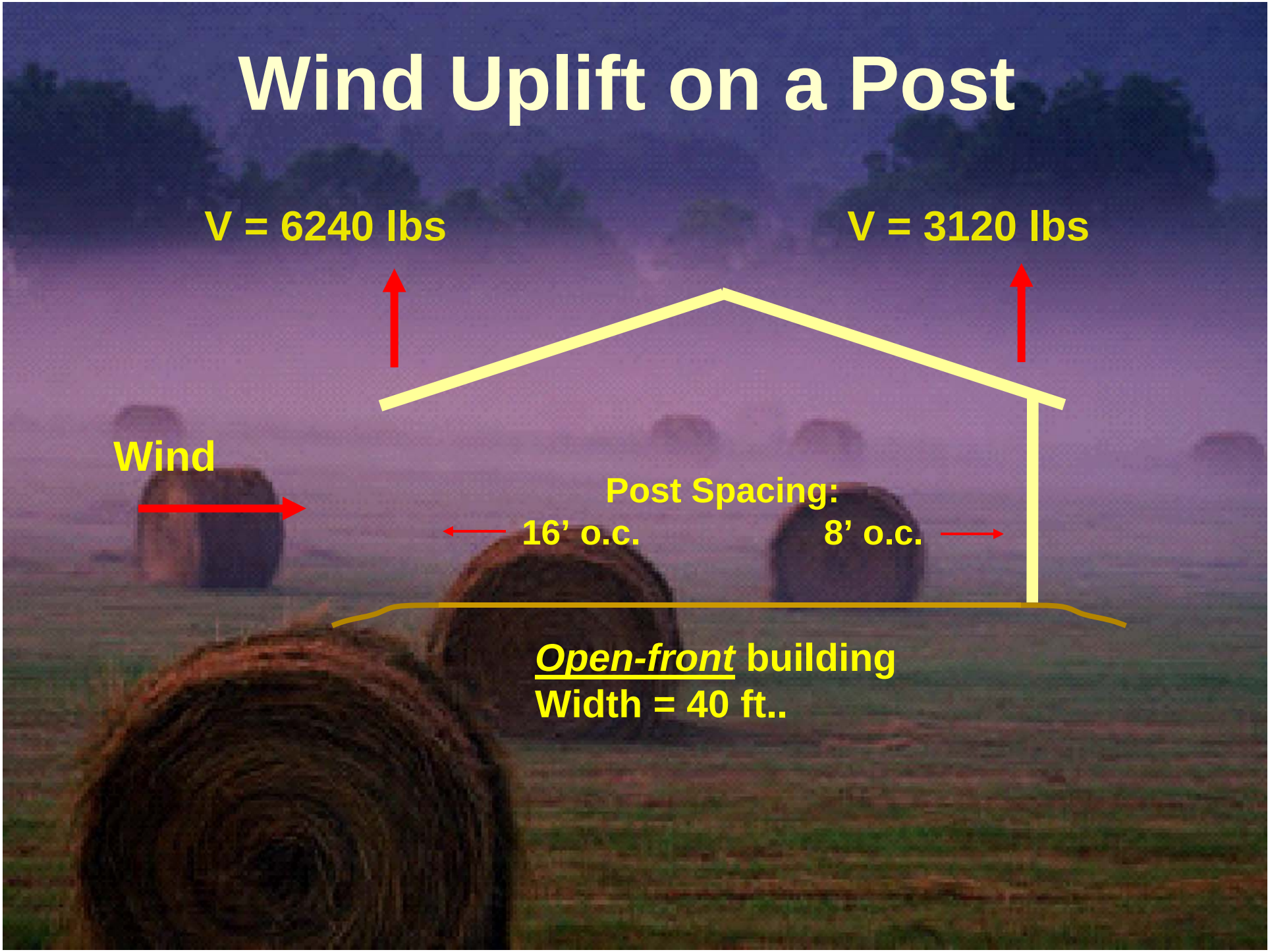
Forces acting on a post



Wind Uplift on a Post



Wind Uplift on a Post



Post size and spacing

- Building HEIGHT and WIDTH are most important variables
- 8-ft post spacing is most common
- Posts require strong foundation to resist both vertical and lateral loads
- Posts designed to be placed 8-ft on-center will be required to resist twice the load of posts placed 4-ft on-center

Post Size & Strength

Post size	Relative strength
4 x 6	0.6
6 x 6	1.0
6 x 8	1.7
8 x 8	2.3

Round poles are sized by top diameter

5”, 6”, 7” and 8” top diameters are commonly used

Sidewall pressure

- Post – Frame Hay Barns are NOT designed for storing hay against the walls
- Steel buildings may require extra sidewall girts to protect metal siding

Bales against
end wall –

Wall bulging
6 to 12 inches

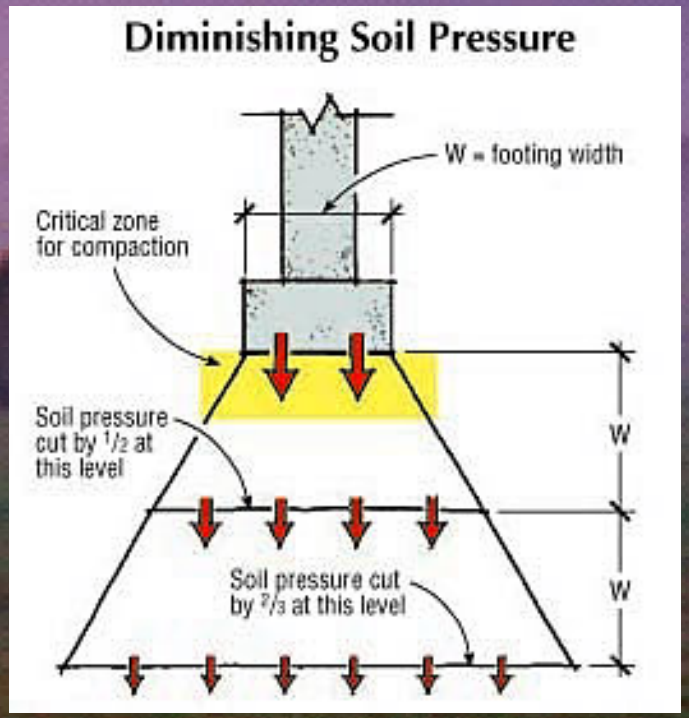
Does this really
look like a
good idea ??

Foundations

- Objective:
  - Limit structural settlement or horizontal movement
  - Resist internal horizontal forces (ex: wind and sidewall loads)
- Components:
  - Post footing
  - Embedment material

Footing

- What does it do?
  - Footings spread out the weight of the barn so the soil carries the load.
- Diameter and thickness of concrete pad:
  - Vertical loads acting on the post
  - Ability of the soil to support the load
  - Size of post
- Types:
  - Cast-in-place concrete
  - Concrete casings or full collars



Footing size

Minimum recommended footing size, diameter (in) for 30 lb/ft^2 vertical load

Building width (feet)	Post spacing (feet)	Soil bearing capacity	
		1500 lb/ft^2	2000 lb/ft^2
32	6, 8	20, 24	16, 20
40	6, 8	24, 28	20, 24
48	6, 8	24, 28	24, 24
60	6, 8	28, NR	24, 28

20-in diameter footing – use 6-in min pad thickness
24-in diameter footing – use 8-in min pad thickness
28-in diameter footing – use 12-in min pad thickness

Source: NRAES-1

Embedment

- What is it?
  - Material placed between post and bored hole
  - Pose base restraint
- What does it do?
  - Provides lateral strength to resist post deflection
  - Resists wind uplift -- Keeps post in ground
- Which materials?
  - Concrete, well-graded granular aggregate, gravel, sand
  - Too much clay will make a poor foundation with little stiffness

Good and poor embedment

Post embedment depth

Embedment depths (inches) for buildings up to 60-ft wide
Wind speed of 90 mph

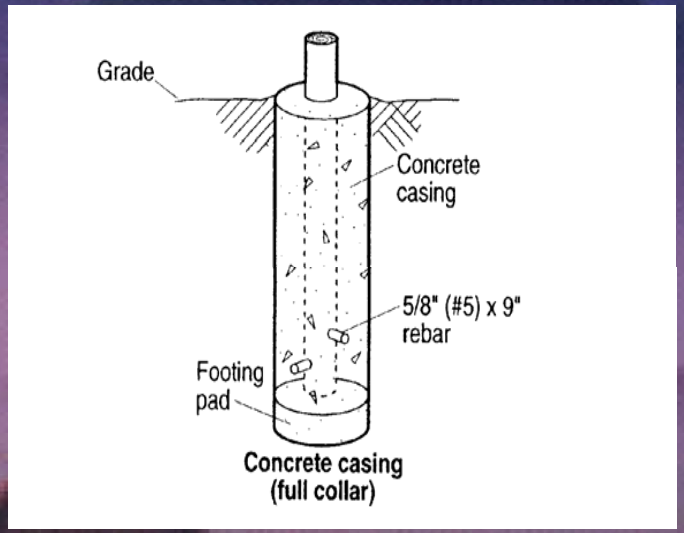
Source: NRAES-1

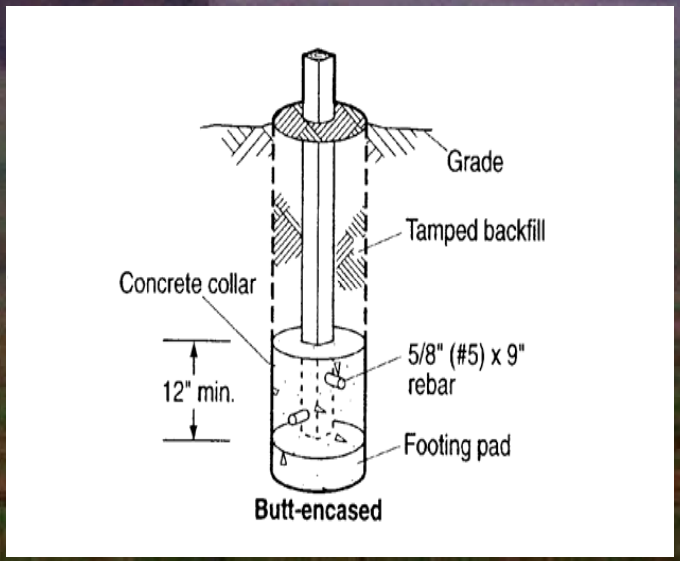
Post spacing (feet)	Eave height (feet)					
	12		14		16	
	SS	SG	SS	SG	SS	SG
6	66f	54	66f	60	66f	66
8	66f	60	66f	66	NR	66f
10	66f	66f	66f	66f	NR	66f

To be used in the absence of building codes and soil tests; it is advisory only.

Typical concrete casings

- Benefits:
  - On posts next to large doors
  - In poorly drained soils
  - For posts that cannot be fully embedded because of isolated rock
  - For posts in front buildings with posts spaced 10-ft or more apart





Specifying Trusses

- Span
  - Measure to outside of truss supports
- Spacing between trusses
- Roof slope
- Bottom chord slope
- Overhang at eave
- Top chord end cut
  - Plumb, horizontal, angle

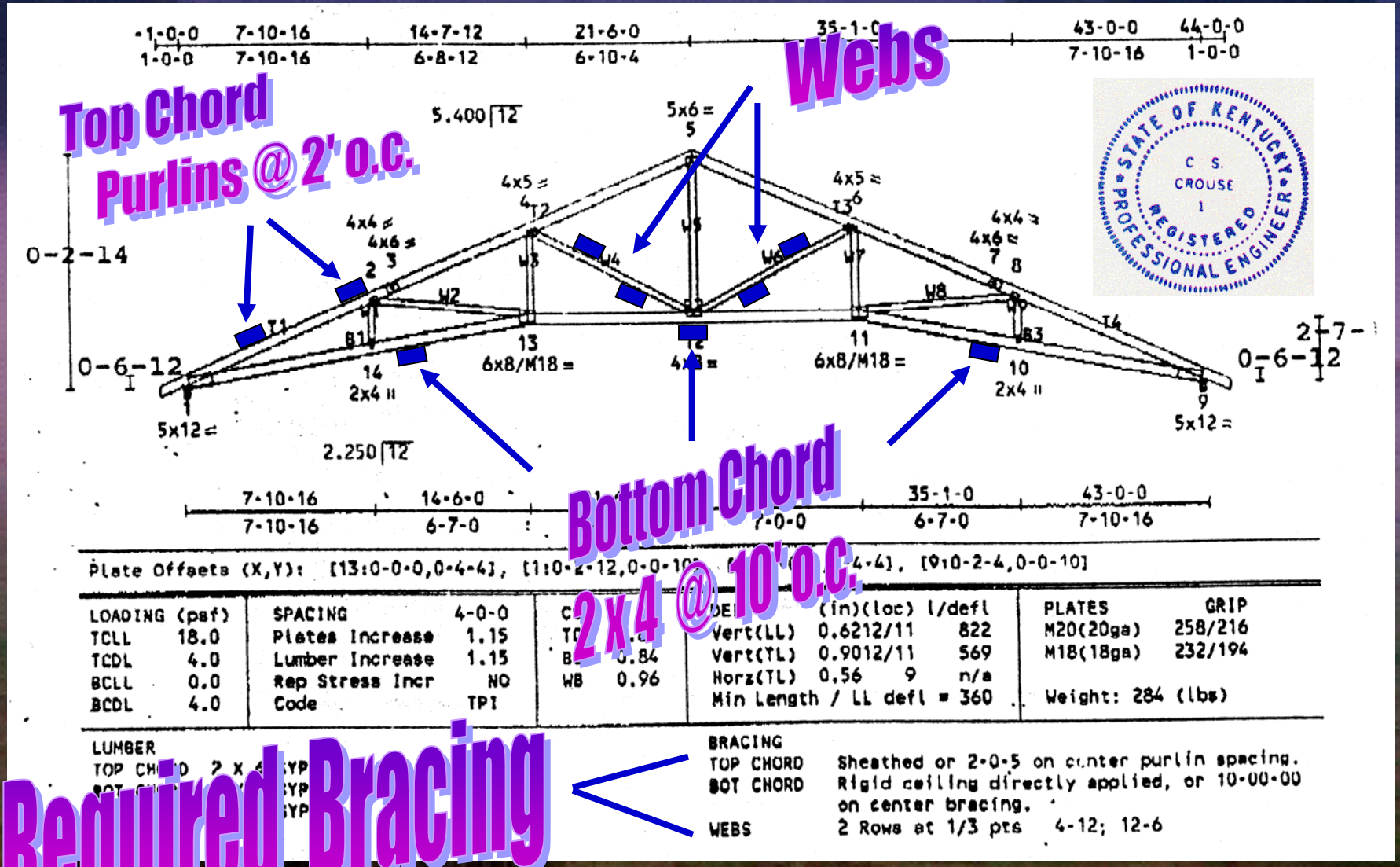
Specifying Trusses

- Loading
  - Live Loads
    - Snow, Equipment, Storage
  - Dead Loads
    - Trusses, Roof materials, Ceiling, Insulation
  - Concentrated Loads (amount & location)
    - Examples: Hoist, Permanent equipment
  - Wind Loads
    - 90 mph (3-sec gust) – most common – (ASCE 7-95)
    - 70 mph (fastest mile) – (ASAE EP 288.5)
- Design by TPI 1-1995
  - Truss Plate Institute (TPI) trade assoc. establishes design standards for metal plate trusses

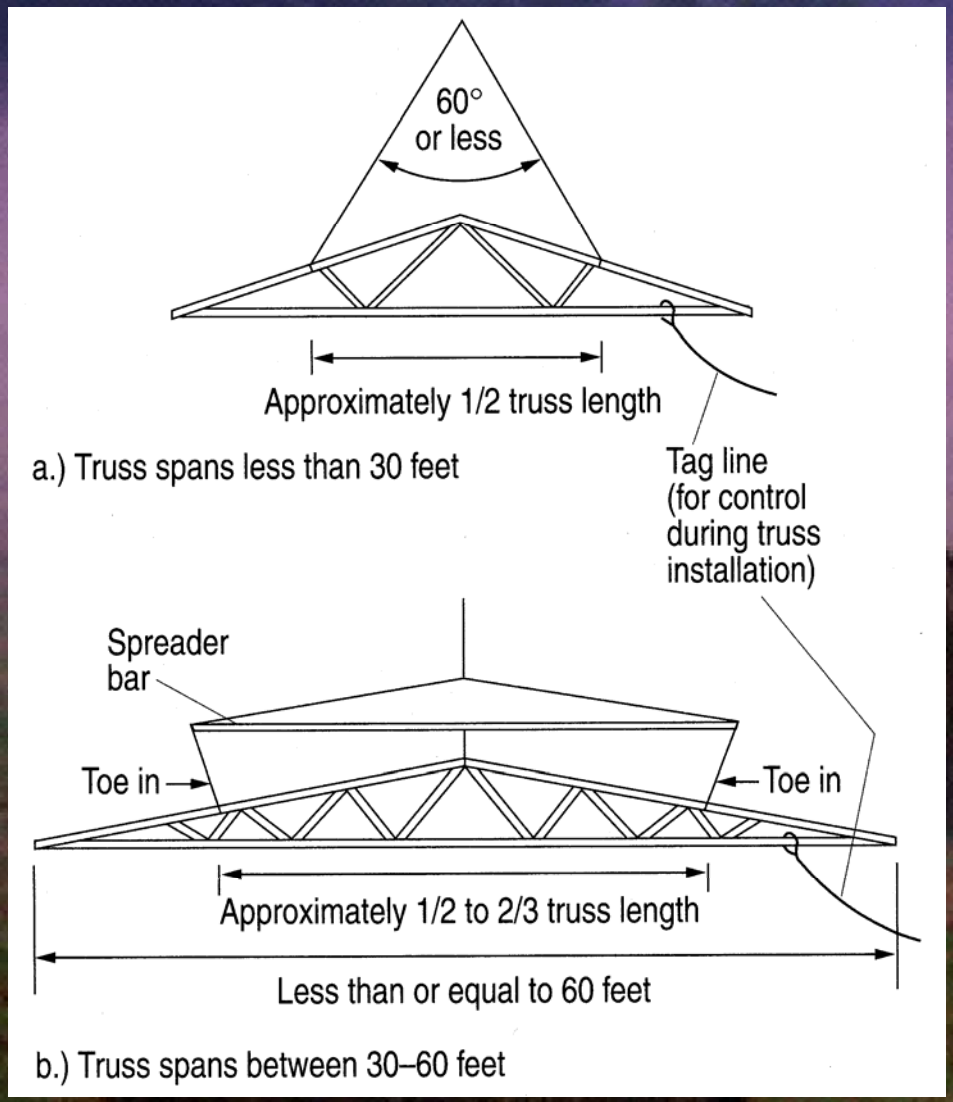
Snow & Dead Loads

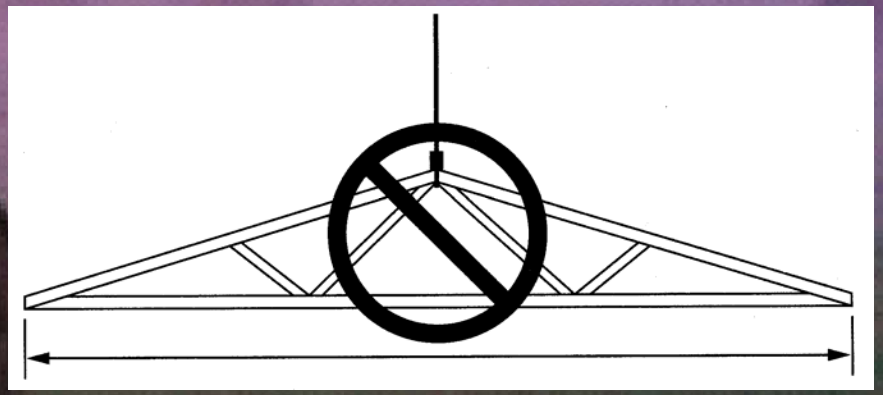
- Roof (truss) Loading
  - Top Chord
    - Live Load (snow) -- 18 psf
    - Dead Load (metal & wood) -- 5 psf
  - Bottom Chord
    - Live load (equipment, storage) – 0 psf
    - Dead Load (truss, ceiling, braces) - 2 psf
  - Total load = 25 lbs per square foot

Your Truss Design Info

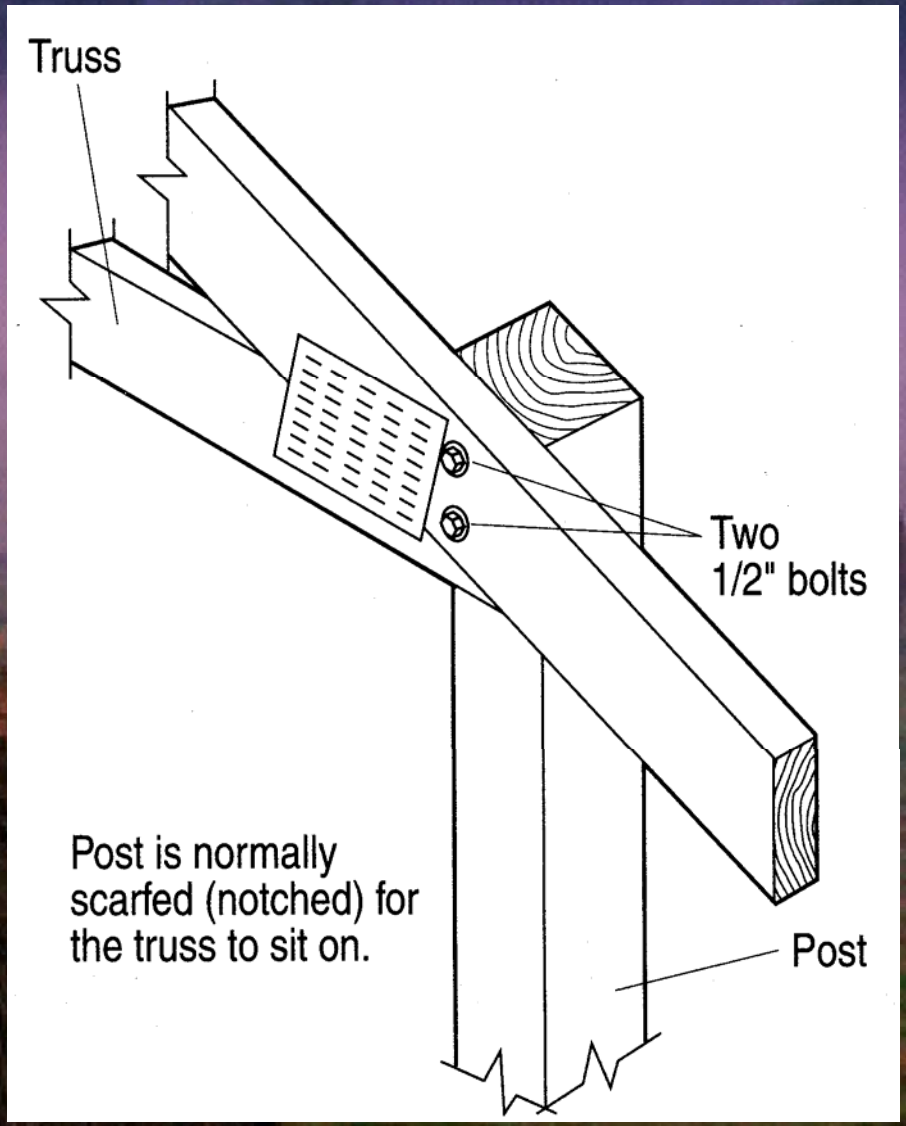


Lift trusses carefully

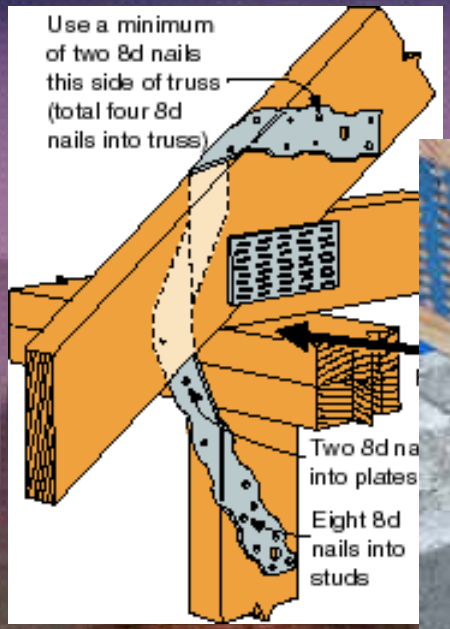




Truss-post connection

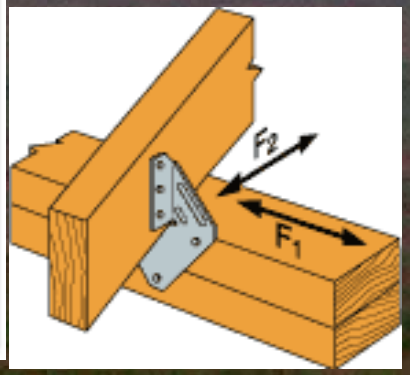


Truss Anchors



STRAPS

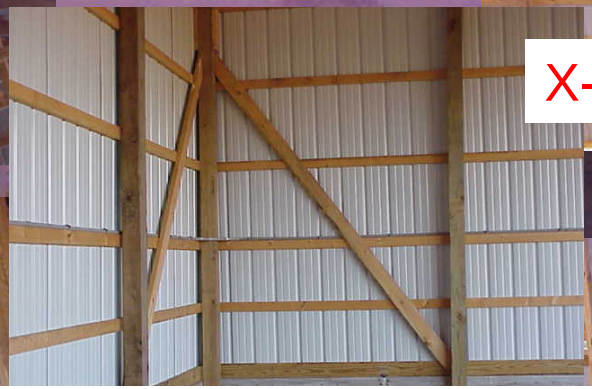
CLIPS



Install the Bracing

Braced in 2 directions

X-bracing @ mid-length



Wall bracing @ corners

Knee brace to top chord

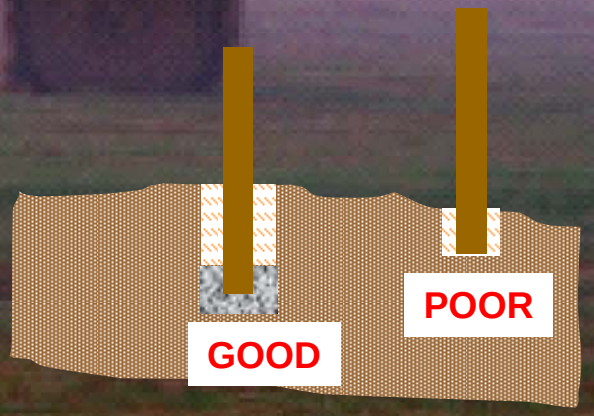
X-bracing @ end wall

Post – Frame Top 5 List

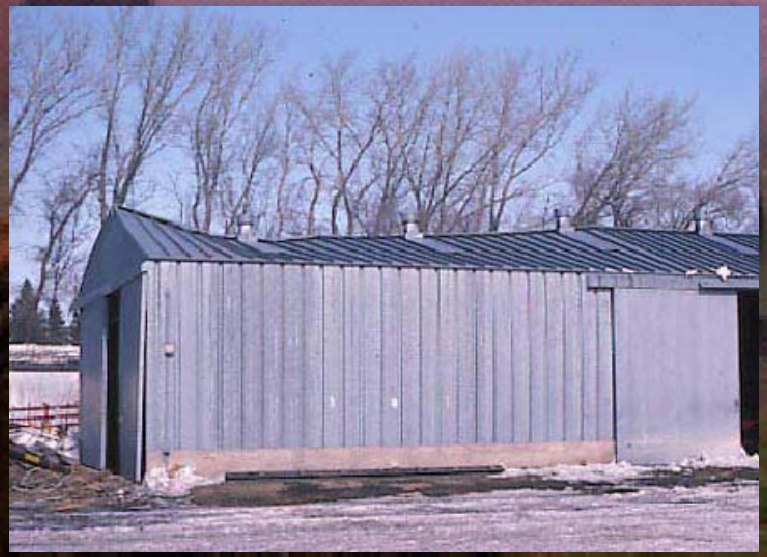
- Don’t build in a hole – Keep water out!
- Properly treated posts – Set them well
  - 0.6 pcf CCA
  - 4 to 5 feet deep, concrete pad & collar
- Keep trusses straight, plumb & anchored
- Don’t skimp on the bracing
- Screw the metal down

How farm buildings fail

- Truss spacing
- Raised lower chords
- Transfer of roof load to posts
- Wind loads
- Joints and lumber quality
- Foundation failures
- Building materials failures
- Inadequate construction practices



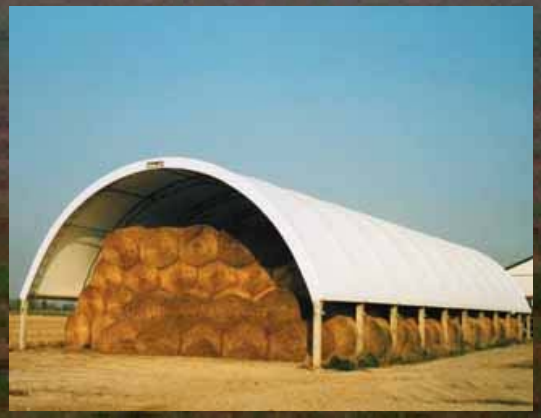
A few examples



Source: Jim Lindley, NDSU

Commercial / Pre-Engineered Options

- Steel Frame
- Steel Arch
- Post-Frame
- Tarp Covered Hoops



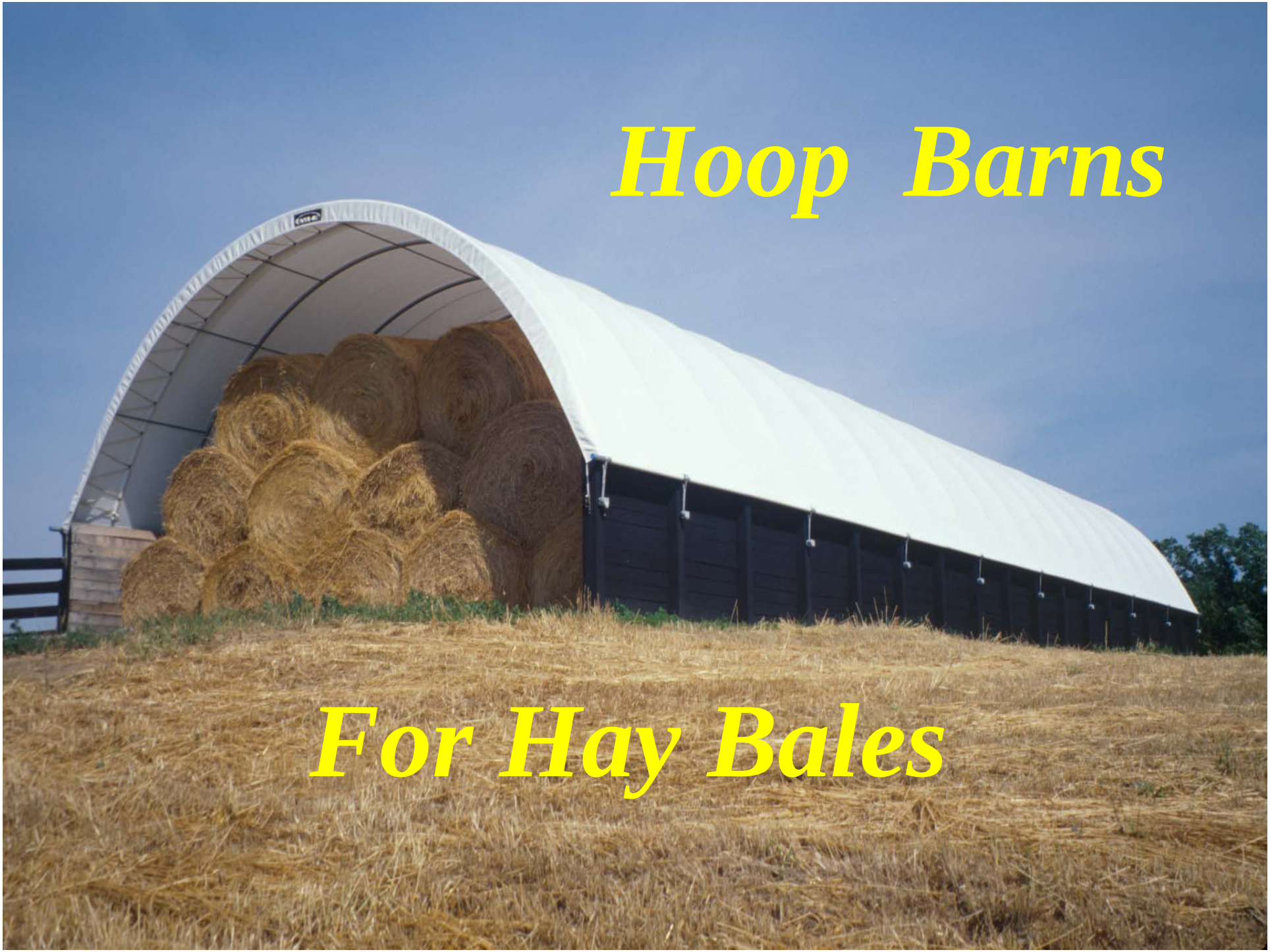
Steel Frame

- More cost competitive for large buildings
- Large clear spans
- Taller sidewall
- May get more clearance in center
- Pre-engineered
- Requires good foundation work

Corrugated Steel Arch

- Variety of sizes
- End access
- High center clearance
- Clearance at sides - ?
- Pre-Engineered
- Requires good foundation work
- Bolts together – similar to grain bin

Hoop Building


Hoop Barns
For Hay Bales

Hoop Barn Features

- Easily Installed
- High Clearance
- Wall Height = Bale Diameter
- Range of sizes
- End access only
- Relatively low cost
- May or may not be pre-engineered

Selecting Contractors

- Reputation & References
- Experience with this or that type building
- Membership in a professional association
- Engineering design
- Contractor licensing
- Contractor’s certificate of insurance
- Building permits
- Bidding
- Contract

Signing the Contract

- Know what you are signing
- Who's responsible for this or that?
- Drawings & Specs
- Insurance
- Permits, Inspections, Laws
- Payment Schedule
- Work Schedule
- Warranties

Estimated Construction Costs

Type	DIY	Contract
Hoop	$2.25-$2.75	$3.00-$4.00
Post-frame		
Roof only	$2.00-$3.00	$3.00-$4.50
Open front	$2.75-$4.00	$4.00-$6.00
Enclosed w/doors	$3.50-$5.50	$5.50-$7.50

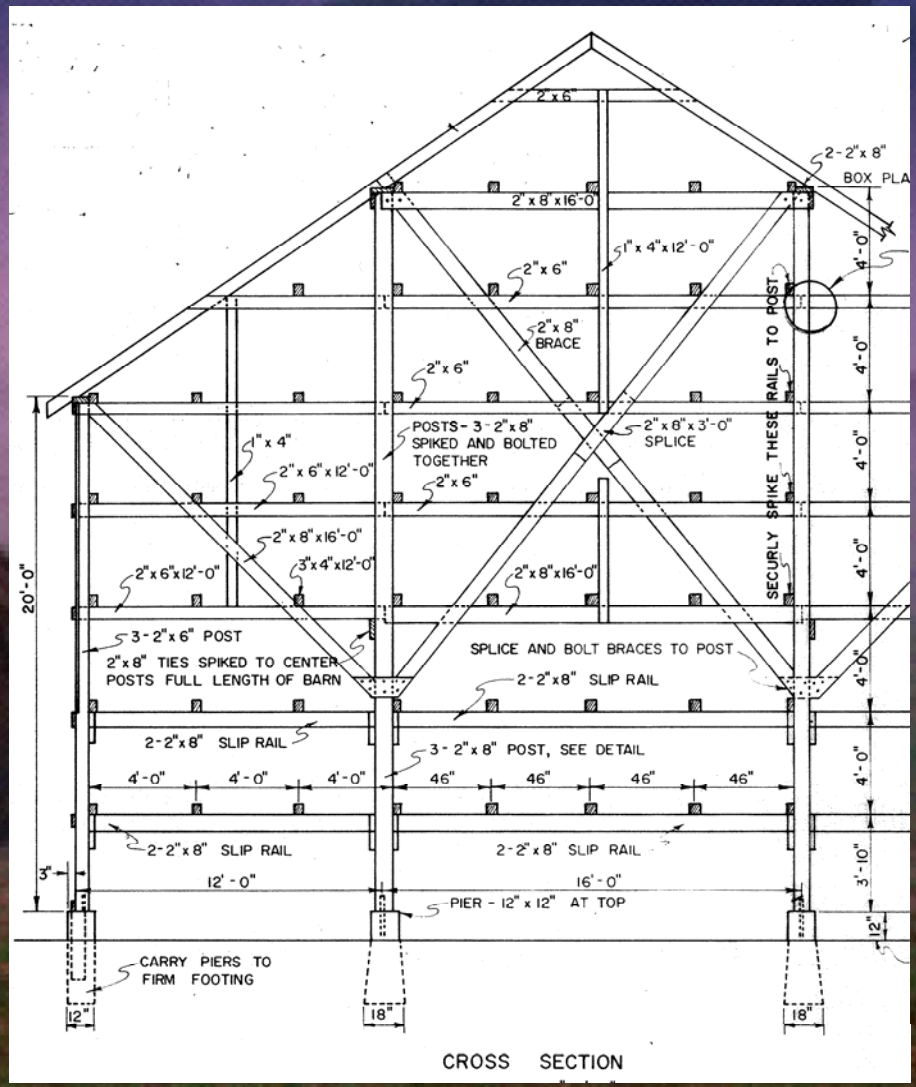
Costs are per sq-ft

Renovating Tobacco Barns

- Common Features
  - Tall
  - Posts on Piers
  - Built-up Posts
  - Bracing for Lateral Strength
  - Tier rails may or may not be structural

Tobacco barns

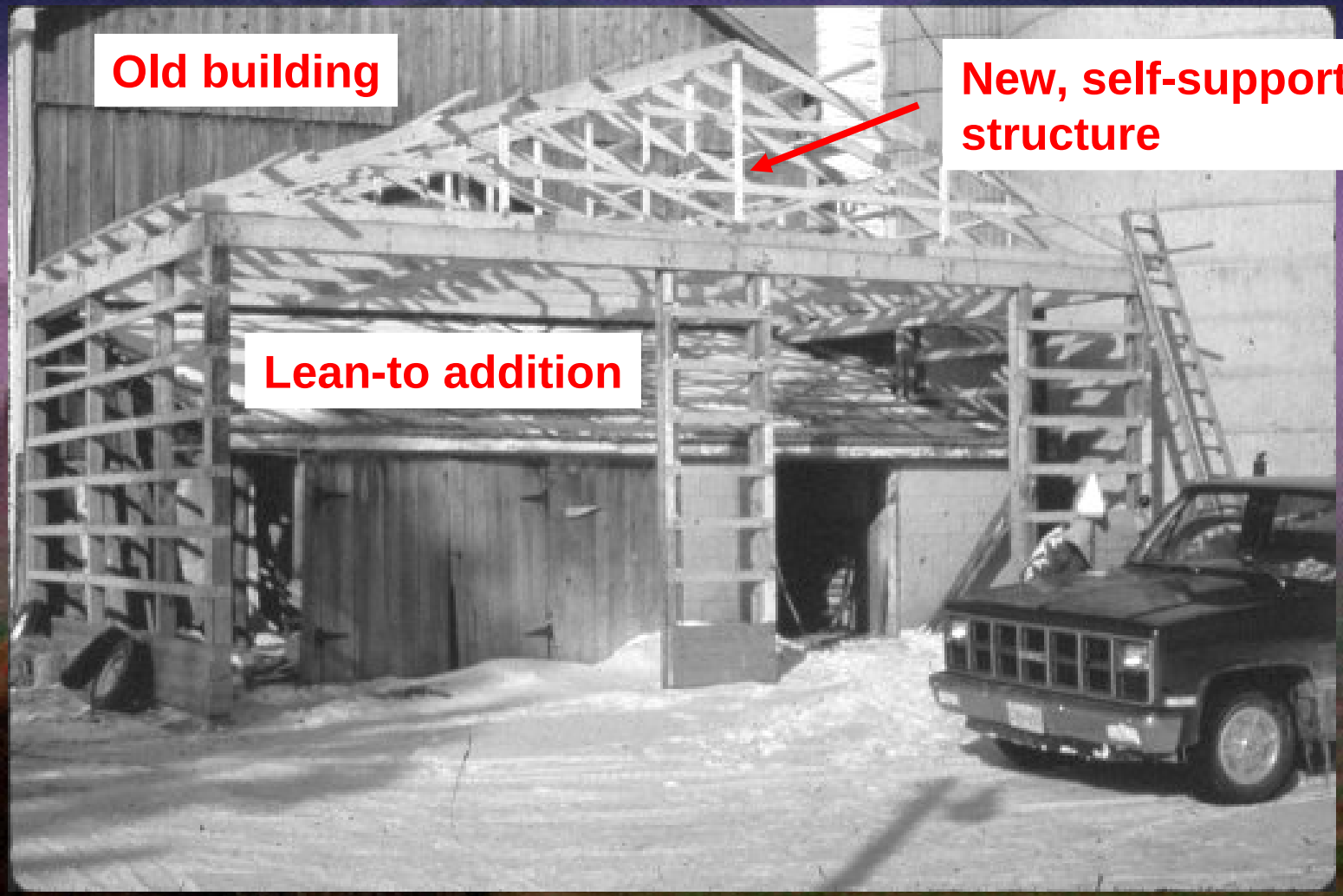
- Bracing is critical
- Tier rails usually do not support frame
- Must leave support for post joints
- Don’t remove diagonal braces
- Don’t try to make a truss out of rafters
- Don’t cut off the posts!



Attachments and Additions

- Existing building may not support more load
- New structure should be self-supporting
- Place posts and footings adjacent to existing building
- Include sufficient wind bracing in the new structure
- Attachments to older buildings should be non-structural

Self-supporting addition



Source: OMAF Factsheet 97-013

Ventilation

- Remove moisture:
  - Hay is not completely dry
  - Respiration generates moisture
  - Moisture can migrate within the stack
  - Condensation & drip from metal roofs
- Example:
  - 50 bales @ 1200 lb = 60,000 lbs
  - @ 20% moisture content, 12,000 lbs water
  - @ 15% moisture content, 8,500 lbs water
  - 3,500 lbs water (420 gal) must leave

Ventilation

- Air exchange is key:
  - Natural ventilation
- Buildings open only at one end need vents in the opposite end wall
- Ridge vents for tight buildings
- Air inlets at bottom


Let’s Be Careful Out There !

Be Sure It's Dry

← *75' Clearance to Other Buildings* →

Preventing Hay Fires

- Key factor is moisture
  - Large packages 15 – 18%
  - Square bale 20 – 25%
- Wait 2 weeks before stacking
- Check temperature
  - Less than 130 F --- OK
  - 130 to 140 ---- Monitor closely
  - 150 F --- Move It !

Be Safe Handling Bales

- ROPS on tractor – Fasten your seat belt
- Tractor weight & counterweight adequate for size of bales
- Adjust wheels to widest position
- Transport up/down slopes
- Towed weight less than tractor weight
- No riders allowed
- Solid & level surface when stacking
- Only operate lift controls from the seat


Thank You
UK Biosystems & Agricultural Engineering
www.bae.uky.edu/ext/HayStorage

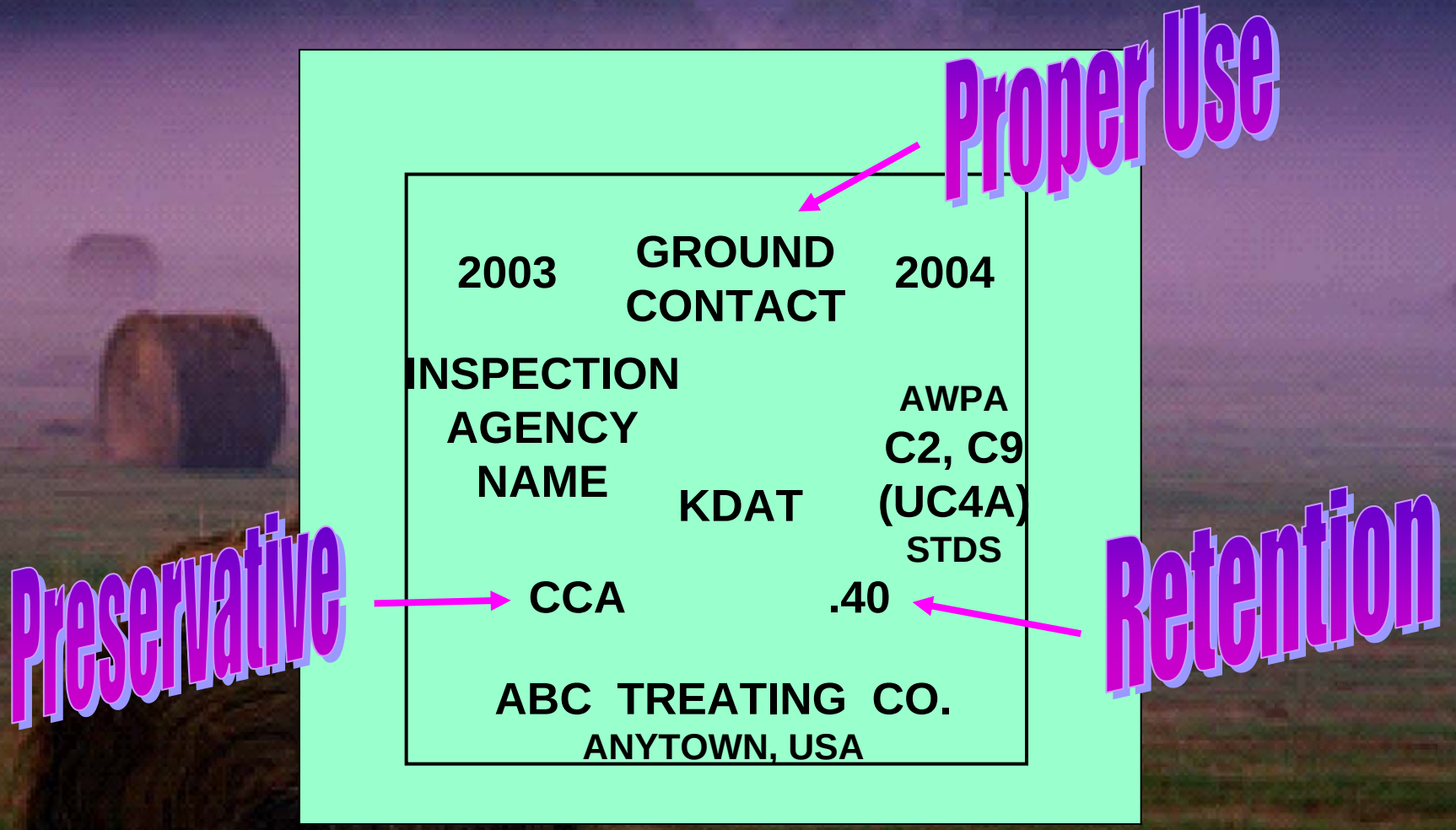
Post size and spacing

Maximum spacing of Southern Pine (no. 2) posts
90 mph wind (q = 18.6 lb/ft²)

Post	Eave height (ft)			
	10	12	14	16
6 x 6	5.7	NR	NR	NR
6 x 8	10.5	7.3	5.4	4.1
6 x 10	16.9	11.7	8.6	6.6
8 x 8	14.4	10.0	7.3	5.6

Post spacings shown in orange should not exceed 8-ft without proper design consideration of increased load on girders, purlins, girts, and foundations.

Typical Quality Mark for Treated Lumber



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Costs are per sq-ft