Hip and Valley Support Location in Wood Framing

P. Hajyalikhani, B. Hudson, D. Boll, L. Boren, Z. Sparks, M. Ward

Abstract—Wood Light frame construction is one of the most common types of construction methods for residential and light commercial building in North America and parts of Europe. The typical roof framing for wood framed building is sloped and consists of several structural members such as rafters, hips, and valleys which are connected to the ridge and ceiling joists. The common slopes for roofs are 3/12, 8/12, and 12/12. Wood framed residential roof failure is most commonly caused by wind damage in such buildings. In the recent study, one of the weaknesses of wood framed roofs is long unsupported structural member lengths, such as hips and valleys. The purpose of this research is to find the critical support location for long hips and valleys with different slopes. ForteWeb software is used to find the critical location. The analysis results demonstrating the maximum unbraced hip and valley length are from 8.5 to 10.25 ft. dependent on the slope and roof type.

Keywords—Light wood framed, bracing, construction, hip, and valley, slope.

I. INTRODUCTION

WOOD framed construction is the most popular method of construction in the residential buildings. Wood frame buildings are economical, provide heat and cool protection, and are the most comfortable of all the types of framing constructions. It is also popular because it is ever changing and able to adapt to fit almost any environment. There are so many structural and architectural possibilities with wood framing that make it a great option when deciding what materials to use for the frame of the building. The majority of residential, commercial and industrial buildings and apartments in North America are wood framed houses [1], [2], [6]. The most common type of wood frame used is platform framing, also known as stick framing. Stick framing roofs are usually sloped from 3 inches of rise per 12 inches of rafter length (3/12), to steep slopes of more than 12 inches per 12 inches of rafter length (12/12) to provide a sloping surface intended to shed rain or snow. The primary roof covering on residential buildings are asphalt shingles, clay and concrete tile, and metal roofing. The more commonly used roof shapes are gable and hip roofs. Gable roofs have horizontal joists; rafters rest on the exterior wall plates and slope upward to connect at a center ridge board. Hip roofs consist of the ceiling

joist, hip and ridge, and it is a type of roof where all the sides downwards to the walls, with a fairly slope. Often these roof types are used in combination and consist of multiple hips, gables and valleys [5]. The hip and valley are structural members in a roof frame where two roof areas join and they are 2 inches deeper than the adjoining rafters [6], [7]. According to the IRC and IBC 2018, if the roof slope is equal or more than 3/12, hip and valley shall be braced at the ridge to a bearing wall/beam or be designed to carry and distributed the specific load at the point [7], [8]. Due to the light weight and possible weak links in the vertical load paths, wood framed houses are highly vulnerable to damage from extreme wind events such as tornadoes. These events can result in significant losses in these buildings [3], [4]. The general loose magnitude is similar for tornadoes and hurricanes in the United States [11]. Many studies have been performed to find the failure modes in residential buildings which are related to the vertical load path between the structural members and the roof and wall covering systems [10], [12]. According to the prescriptive design requirements and visual inspection of the damage photos, a possible cause of vulnerability among stick frame roofs is the long unsupported structural member lengths [10]. The main important behavior of the wood frame houses under the extreme wind event is to ensure safety of the residents and minimized damage to interior content. Therefore, bracing the long hip and valley at the ridge point is not sufficient and should be support in multiple locations, depending on the length, to carry and transfer the load to the bearing partition. In addition, braced closely hip and valley could maintain the integrity of the roof structure members.

II. HIP AND VALLEY ANALYSIS ASSUMPTIONS

The above-mentioned construction issues could be minimized by designing the bracing location for hip and valley.

ForteWeb is the most commonly used software in North America, which provides design solution for the structural members in stick framing. ForteWeb software supports International Building Code (IBC) which is most commonly used in United States and National Building Code of Canada (NBCC). The design methodology is allowable stress design (ASD) and using Limit States Design (LSD). Also, in this software, U.S. Glulam and visually graded dimensional lumber are analyzed based on the referenced version of the NDS Supplement-Design Values for Wood Construction [9] and Canadian visually graded dimension lumber are analyzed based on the referenced version of CAN/CSA O86.

A. Assumptions

In this research two types of roof covering were evaluated, composite shingle and concrete tile with the common slopes of

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3, 8, and 12 inches of rise per 12 inches of rafter length. According to IRC and IBC 2018, load and deflation criteria are defined and shown in Tables I and II. Live load for composite shingle and concrete tile roof is equal to 20 psf and dead load for composite shingle and concrete hip roof is 10 and 20 psf. The live load deflection is an assumed length of the hip and valley divided to 240 (L/240) and the total load deflection is considered length divided to 180 (L/180).

_		TABLE I Load Criteria			
	Roof type	Dead Load (psf ^a)	Live Load (psf ^a)		
	Composite Shingle	10	20		
_	Concrete Tile	20	20		
^a p	^a psf is pound per square feet.				

	TABLE II DEFLATION CRITERIA
Load type	Deflection
Live Load	L/240
Total Load	L/180

^aL is length of the member.

TABLE III Hip, Valley, and Rater Size				
Roof Slope Hip and Valley size (inch) Rafter size (inch)				
3/12	2x8	2x6		
8/12	2x8	2x6		
12/12	2x8	2x6		
TABLE IV				

ROOF SLOPE AND RAFTER SPACING		
Roof Slope for Hip and Valley		Rafter Spacing (inch)
3/12		24
8/12		24
	12/12	24
TABLE V Lumber Species and Overhang		
	TABLE V Lumber Species and	7 OVERHANG
Roof Slope	TABLE V LUMBER SPECIES AND Hip, Valley, and R	7 OVERHANG after Overhang (inch)
Roof Slope 3/12	TABLE V LUMBER SPECIES AND Hip, Valley, and R Southern Pine NO	7 OVERHANG after Overhang (inch) 0.2 2
Roof Slope 3/12 8/12	TABLE V LUMBER SPECIES AND Hip, Valley, and R Southern Pine NO Southern Pine NO	7 OVERHANG after Overhang (inch) 0.2 2 0.2 2

The most common type of the wood for hip and valley is Southern Pine NO.2. The common nominal size of the rafter in stick framing roofs is 2 by 6 inches (the actual size of the rafter is equal to 1.5 inch to 5.5 inch). As a result, the nominal size of the hip and valley is 2 inches thickness by 8 inches depth (the actual size is 1.5 inch to 7.25 inch) because depth of hip and valley shall not be less in depth than the cut end of the rafter [6], [7]. According to International residential and building code 2018 (IRC 2018 and IBC 2018), the maximum unsupported length for 2 by 6 inches rafter for composite shingle and concrete tile roof are 11 feet and 9.5 feet respectively. Therefore, the maximum length of the rafter is picked up less than 9.5 ft. Hips and valleys are supported by a perimeter wall on one side and connected to the ridge by the hanger on the other side. The typical clear overhang is 2 ft. The wall thickness is 4 inches. Roof slope, hip, valley and rafter size and material type used in Forteweb analysis are demonstrated in Tables III-V.



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Member Pitch								
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Bottom Edge Bracing (Lu): Bottom compression edge must be braced at 16°5° of based on loads applied, unless detailed off

 Bottom Edge Bracing (Lu): Bottom compressi Upward deflection on left cantilever exceeds 0
 Applicable calculations are based on NDS.

Fig. 1 Hip, shingle roof and 12/12 slope

The ForteWeb analyses for hip and valley members with a 12/12 slope which are loaded by shingle and tile roof are shown in Figs. 1 and 4. In the ForteWeb analysis, first the deflection criteria are assumed based on IRC 2018, which is L/ 240 for live load and L/180 for total load (L is length of the unbraced hip or valley). Second, the type of the roof, live load, dead load, overhang length, hip or valley unsupported length and slope of the roof are defined. Third, the member size and material type are picked up which is 2x8 Southern Pine No.2.

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of capacity.

Finally, analysis is performed to find the maximum unsupported length for hips and valleys with different slopes.

Member Info System: Roof Member: Hip/Valley Be er Info Spans & Suppo Loads Location Analysis System: Roof Member Pitch 8.49 /12 Member Pitch 8.49 /12 Deflection Criteria Code Minimum 🗸 Deflection Criteria Code Minimum 🖌 Live Load: L/ 240 Total Load: L/ 180 Live Load: L/ 240 Total Load: L/ 180 ember Info Location Analysis Roof Geometry Spans & Supports Loads Product Selection Solutions Type Clear Roof Values High End Support Face Mount Hange ember Info Roof Geometry Spans & Supports Loads Location Analysis Product Selection Hip Bean ~ High End Support Face Mount Hanger Туре Clear Roof Values ng Valley Beam ~ Loading (PSE) 2 Live Type 12 / 12 Root Loading (PSF) Roof 12 / 12 Live Type Live 7' 4 3/16' ~ 20.0 Roof 6191 Dead Live 20.0 20.0 12 / 12 Dead Roof Slope Intermediate Supp 10.0 12 / **12** Include Dimension fr Intermediate Support Side Wall Include MEMBER REPORT Dimension from FORTE WEB Level, Roof: Hip Bear 7' 4 3/16' Side Wall ~ 1 piece(s) 2 x 8 Southern Pine No. 2 Sloped Length: 15' 6 3/16 MEMBER REPORT Level, Copy of Roof: Valley Bean FORTE WEB PASSED 1 piece(s) 2 x 8 Southern Pine No. 2 PASSED Length : 15' 7" Roof ber Length : 13' 1 15/16" im : Roof Sloped Length: 13' 1 1/16' stem : Root ember Type : Flush Beam ilding Use : Residential ilding Code : IBC 2018 8.49 em : Roof iber Type : Flush Beam fing Use : Residential fing Code : IBC 2018 on Methodology : ASD n Methodology : A er Pitch : 8.49 /12 2'9 15/16 9'6 9/16 ASD r Pitch : 8.49 /12 1 8.49 10' 4 3/4' ide face of left All lo os are m Design Results Actual @ Locati Allow Result Load: Combin ation (Pat 1 Member Reaction (lbs 687 @ 12' 4 1/2" 1271 (1.50") Passed (54%) 1.0 D + 1.0 Lr (Alt Spans) All d Shear (lbs) 580 @ 11' 10 9/16' Passed (37%) 1.0 D + 1.0 Lr (Alt Spans) 1586 Load: Combination (Patt Design Results Actual @ Location Allowed Result Moment (Ft-lbs) 1217 @ 8 6 1/8 1266 Passed (96%) 1.0 D + 1.0 Lr (Alt Spans) 642@2" 2231 (3.50") Passed (29%) 1.0 D + 1.0 Lr (All Spans) 0.183 @ 7' 10 1/2' Live Load Defl. (in) 0.576 ssed (L/756 1.0 D + 1.0 Lr (Alt Spans) Shear (lbs) 506 @ 9 7/16 1586 Passed (32%) 10 D + 10 Lr (All Spans) Total Load Defl. (in) 0.414 @ 7' 10 13/16" 0.768 Passed (L/333) 1.0 D + 1.0 Lr (Alt Spans) 1266 Moment (Ft-lbs) 1215 @ 4' 6 3/16' Passed (96%) 1.0 D + 1.0 Lr (All Spans) Deflection criteria: LL (L/240) and TL (L/180 Live Load Defl. (in) 0.284 @ 5' 1 3/16' 0.626 Passed (L/530) 1.0 D + 1.0 Lr (All Spans) Demection Criteria: LL (2240) and TL (2150). Overhang deflection criteria: LL (2240) and TL (22180) Top Edge Bracing (Lu): Top compression edge must be b Bottom Edge Bracing (Lu): Bottom compression edge mu demiceble activations on brand en XDP. Total Load Defl. (in) 0.503 @ 5' 1 1/4" 0.835 Passed (L/299) 1.0 D + 1.0 Lr (All Spans) ed otherwise. Deflection criteria: LL (U240) and TL (U180) Top Edge Bracing (Lu): Top compression ed Bottom Edge Bracing (Lu): Bottom compress Applicable calculations are based on NDS. a must be braced at 3' 2" o/c based on loads applied, unless detailed otherwise. on edge must be braced at 12' 9" o/c based on loads applied, unless detailed oth Fig. 2 Hip, tile roof and 12/12 slope

TABLE VI

MAXIMUM UNSUPPORTED LENGTH FOR COMPOSITE SHINGLE/HIP				
Roof material and type	Roof Slope	Clear Unsupported Length (ft) ^a		
Shingle/Hip	3/12	10.3		
Shingle/Hip	8/12	10.1		
Shingle/Hip	12/12	10		
^a (ft) = feet				

The maximum unsupported length for hip and valley based on ForteWeb analysis, are demonstrated in Tables VI-IX. The

Fig. 3 Valley, shingle roof, and 12/12 slope

maximum clear unsupported length is calculated when the

moment in hip and valley has approximately reached to 95%

TABLE VII				
MAXIMUM UNSUPPORTED LENGTH FOR COMPOSITE TILE/ HIP				
Roof material and type	Roof Slope	Clear Unsupported Length (ft) ^a		
Tile /Hip	3/12	9.6		
Tile / Hip	8/12	9.1		
Tile / Hip 12/12 8.7				
$a(\mathbf{h}) - \mathbf{f}_{oot}$				

(ft) feet



Fig. 4 Valley, tile roof and 12/12 slope

ed at 11' 4" o/c based on loads ap

st be braced at 3' 8" o/c ba dge must be braced at 11'

Deflection criteria: LL (L/240) and TL (L/180) Top Edge Bracing (Lu): Top compression ed Bottom Edge Bracing (Lu): Bottom compres

TABLE VIII Maximum Unsupported Length for Composite Shingle/Valley				
Roof material and type Roof Slope Clear Unsupported Length (ft) ^a				
Shingle/Valley	3/12	10.3		
Shingle/Valley	8/12	10		
Shingle/Valley	12/12	9.7		
$a^{a}(ft) = feet$				

IV. CONCLUSION

The support location in wood framing for hip and valley is proposed in this study. The analysis result indicates that the hip and valley bracing at the ridge point (IRC 2018, IBC 2018) is not sufficient. Consequently, these members shall be braced closely. Due to the analysis result, for shingle roofs, hips and valleys shall be braced at 10 ft and 9.7 ft, respectively, and for a tile roof, hips and valleys shall be braced at 8.7 ft and 8.4 ft, respectively.

ΤA	ΒI	E	IX
		_	177

MAXIMUM UNSUPPORTED LENGTH FOR COMPOSITE TILE/VALLEY	

Roof material and type	Roof Slope	Clear Unsupported Length (ft) ^a
Tile/Valley	3/12	9.1
Tile/Valley	8/12	8.8
Tile/Valley	12/12	8.4

 $^{a}(ft) = feet$

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