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.

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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

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]psf is pound per square feet.

TABLE II
DEFLATION CRITERIA

Load type	Deflection
Live Load	L/240
Total Load	L/180

[a]L 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

Roof Slope	Hip, Valley, and Rafter	Overhang (inch)
3/12	Southern Pine NO.2	2
8/12	Southern Pine NO.2	2
12/12	Southern Pine NO.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.

III. HIP AND VALLEY ANALYSIS RESULTS

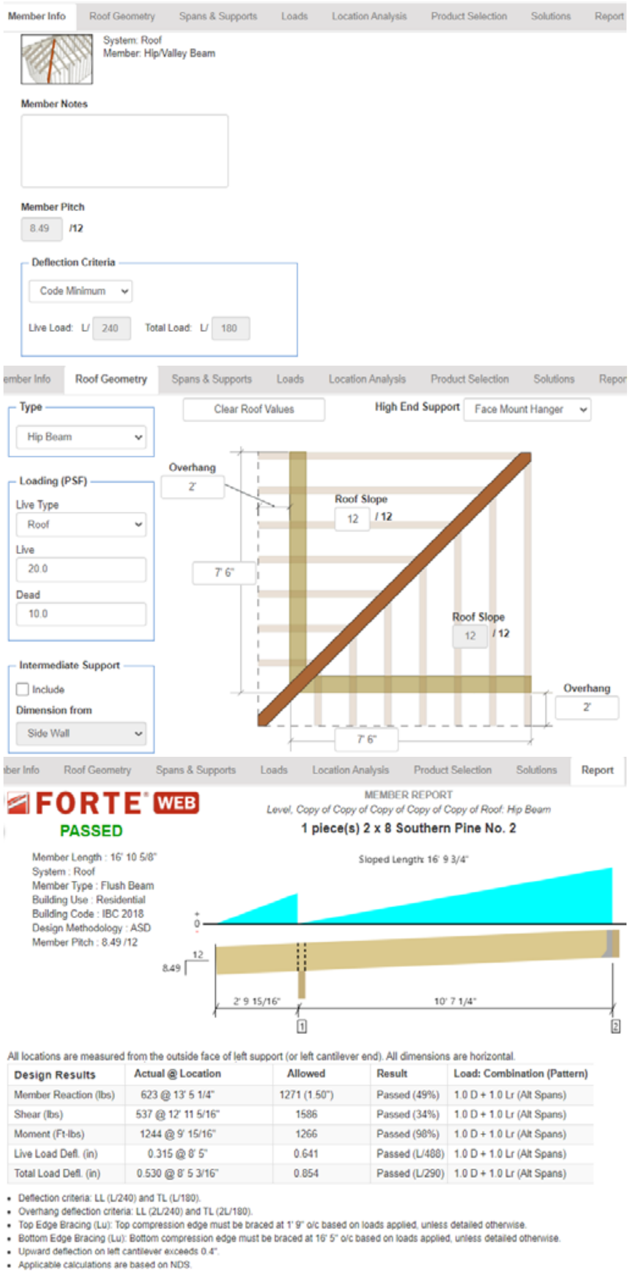

Fig. 1 Hip, shingle roof and 12/12 slope

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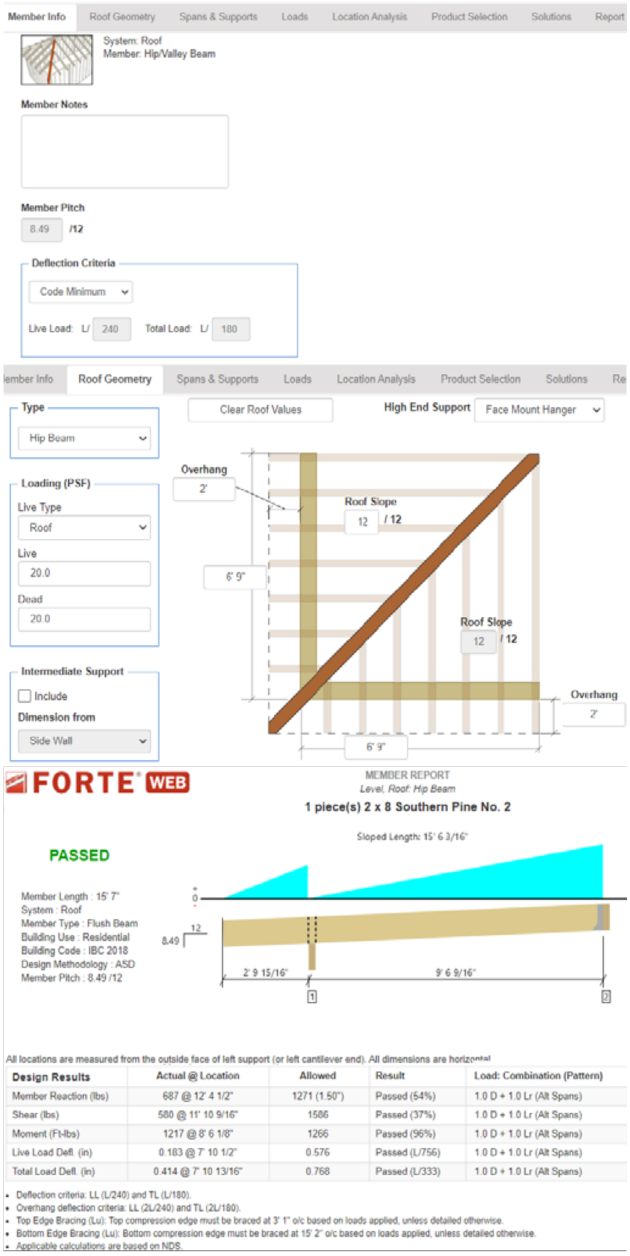
Finally, analysis is performed to find the maximum unsupported length for hips and valleys with different slopes.



Design Results	Actual @ Location	Allowed	Result	Load: Combination (Pattern)
Member Reaction (lbs)	687 @ 12' 4 1/2"	1271 (1.50")	Passed (54%)	1.0 D + 1.0 Lr (Alt Spans)
Shear (lbs)	580 @ 11' 10 9/16"	1586	Passed (37%)	1.0 D + 1.0 Lr (Alt Spans)
Moment (Ft-lbs)	1217 @ 8' 6 1/8"	1266	Passed (96%)	1.0 D + 1.0 Lr (Alt Spans)
Live Load Defl. (in)	0.183 @ 7' 10 1/2"	0.576	Passed (L/756)	1.0 D + 1.0 Lr (Alt Spans)
Total Load Defl. (in)	0.414 @ 7' 10 13/16"	0.768	Passed (L/333)	1.0 D + 1.0 Lr (Alt Spans)

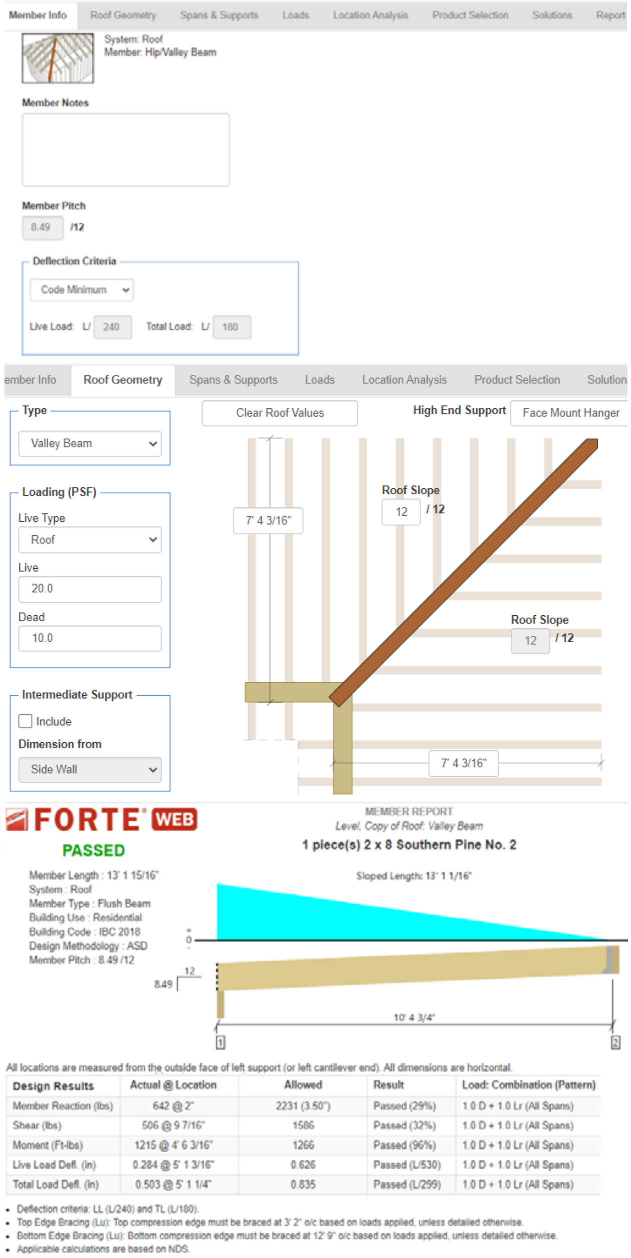
Fig. 2 Hip, tile roof and 12/12 slope

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 maximum clear unsupported length is calculated when the moment in hip and valley has approximately reached to 95% of capacity.



Design Results	Actual @ Location	Allowed	Result	Load: Combination (Pattern)
Member Reaction (lbs)	642 @ 2"	2231 (3.50")	Passed (29%)	1.0 D + 1.0 Lr (All Spans)
Shear (lbs)	506 @ 9 7/16"	1586	Passed (32%)	1.0 D + 1.0 Lr (All Spans)
Moment (Ft-lbs)	1215 @ 4' 6 3/16"	1266	Passed (96%)	1.0 D + 1.0 Lr (All Spans)
Live Load Defl. (in)	0.284 @ 5' 1 3/16"	0.626	Passed (L/530)	1.0 D + 1.0 Lr (All Spans)
Total Load Defl. (in)	0.503 @ 5' 1 1/4"	0.835	Passed (L/299)	1.0 D + 1.0 Lr (All Spans)

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

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] (ft) = feet

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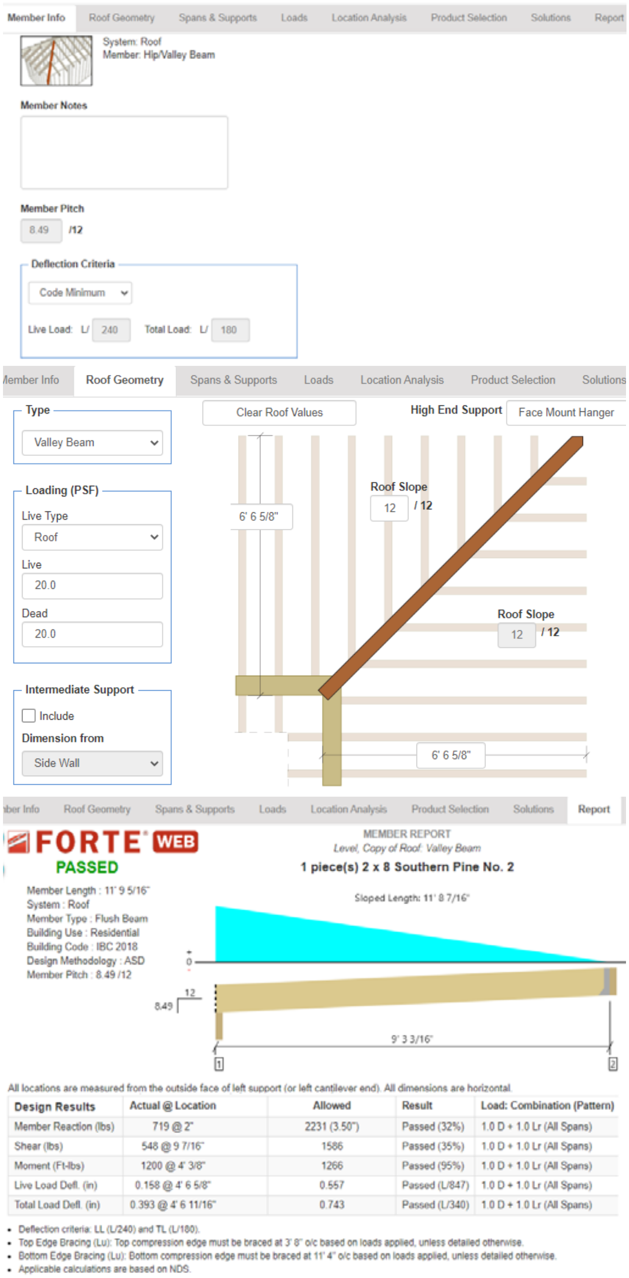

Fig. 4 Valley, tile roof and 12/12 slope

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] (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.

TABLE IX
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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