A SunCam online continuing education course

Repair Techniques for Metal Plated Wood Trusses
Part 3: Complex Truss Repairs

by

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Table of Contents

Introduction

Metal plated wood trusses are engineered products that are manufactured in a controlled environment and are now used extensively in the wood frame construction industry. Wood trusses provide the architect or building designer greater flexibility in the design of the structure than conventional framed (stick-built) construction. The design is not as limiting with regard to bearing wall locations which enables longer spans and greater ability to shape complicated roof and ceiling profiles. These pre-manufactured wood trusses facilitate a quicker construction schedule and an overall lower cost.

Wood, a renewable resource, has a great deal of manufacturing flexibility. Wood members are easily formed into standard framing sizes, cut into appropriate lengths with odd angles if necessary, and attached to form the wood structure. However, wood is more susceptible than steel or concrete to damage due to internal defects, handling issues, and long term deterioration. Design or manufacturing errors, shipping damage, miscommunication, and change orders are possible causes for the inadequacy of a wood truss for a specific application and therefore a repair or modification of the pre-manufactured wood truss is required. The purpose of this course series is to address various repair techniques that could be used to correct damage to the wood members or metal plates, reinforce trusses that do not meet the required specified design loads, or adjust the truss profile or member location to meet other design requirements.

This course is the third part in a three part series which consists of a total of 11 chapters between all three parts. Chapters 1 through 3 provide an introduction to the terms, concepts, and process involved in truss repairs. Chapters 4 through 11 contain actual truss repairs to provide instruction through the use of example. These chapters are broken down as follows

- Part 1: Introduction and Simple Repair Concepts – Five Chapters.
  - Chapter 1 – Definitions
  - Chapter 2 – Repair Design Concepts
  - Chapter 3 – Wood Truss Repair Connections
  - Chapter 4 – Member Damage and Defects
  - Chapter 5 – Plate Damage
- Part 2: Moderate Truss Repairs - Four Chapters
  - Chapter 6 – Manufacturing Errors
  - Chapter 7 – Stubs and Extensions
  - Chapter 8 – Minor Modifications
  - Chapter 9 – Major Modifications
- **Part 3: Complex Truss Repairs** - Two Chapters – Current Part
  - Chapter 10 – Volume Ceiling Changes
  - Chapter 11 – Girder Truss and Truss Loading Modifications.

meter	f-i-s
1	3-03-06
2	6-06-12
3	9-10-02
4	13-01-08
5	16-04-14
6	19-08-04
7	22-11-09
8	26-02-15
9	29-06-05
10	32-09-11
15	49-02-09
20	65-07-06

The dimensions used in this document may be in feet (x’), inches (x”), or feet-inches-sixteenths (f-i-s). The repair examples will usually use feet for larger dimensions such as scab members and inches for the smaller dimensions such as Oriented Strand Board (OSB) gussets. Inches are used for all board and plate sizes (2x4, 2x6, etc.). The f-i-s units will be shown in dimension lines that run along the top and bottom of the trusses as shown on the original truss design drawing. As an example of the f-i-s notation, 10-3-8 equals 10’-3 1/2” (3.14 m) because the last one or two digits in that notation is an unreduced fraction so that 8/16” = 1/2” (13 mm). Throughout the document, a metric equivalent is provided in parenthesis for each dimension of the repair examples. The f-i-s dimensions that run along the top and bottom of the truss are not converted to reduce clutter. Some sample conversions are provided in the chart to the right. When the lumber size is converted to the metric dimensions, it will be the actual board dimensions rather than the rough dimensions. As an example, a 2x4 which has a final cut dimensions of 1 ½” x 3 ½” will be shown as 38 x 89 mm instead of the rough cut dimensions of 51 x 102 mm.

When forces are given in this course, tension forces will have a positive value and compressive forces will be negative.

Tables 3-1 and 5-1 from the first part of the course are repeated below as a reference. This course assumes that the reader is familiar with the terminology and concepts presented in the first part of this course series.

							English Units				Metric Units			
Type	Main Member Lumber Type	Side Member Lumber Type	Specific Gravity main - G_m	Specific Gravity side - G_s	Single or Double shear	DOL (Duration of Load)	Diameter D - in.	Length in main - L_m - in.	Length in side - L_s -in.	Connection Capacity (Z) -lbs	Diameter D - mm	Length in main - L_m - mm	Length in side - L_s -mm	Connection Capacity (Z) -N
Roof	SYP	SYP	0.55	0.55	Single	1.15	0.131	1.50	1.50	122	3.33	38.1	38.1	542
Roof	SYP	SPF	0.55	0.42	Single	1.15	0.131	1.50	1.50	106	3.33	38.1	38.1	471
Roof	SPF	SPF	0.42	0.42	Single	1.15	0.131	1.50	1.50	95	3.33	38.1	38.1	423
Roof	SYP	7/16" OSB	0.55	0.50	Single	1.15	0.131	1.50	0.44	87	3.33	38.1	11.1	385
Roof	SYP	7/16" OSB	0.55	0.50	Double	1.15	0.131	1.50	0.44	173	3.33	38.1	11.1	771
Roof	SYP	3/4" OSB	0.55	0.50	Single	1.15	0.131	1.50	0.72	105	3.33	38.1	18.3	465
Floor	SYP	SYP	0.55	0.55	Single	1.00	0.131	1.50	1.50	106	3.33	38.1	38.1	471
Floor	SYP	SPF	0.55	0.42	Single	1.00	0.131	1.50	1.50	92	3.33	38.1	38.1	410
Floor	SYP	7/16" OSB	0.55	0.50	Single	1.00	0.131	2.56	0.44	75	3.33	65.1	11.1	335
Floor	SYP	3/4" OSB	0.55	0.50	Single	1.00	0.131	2.28	0.72	91	3.33	57.9	18.3	404

Table 3-1 Allowable Shear Capacity for the 10d Gun Nail.

Span Rating	Thickness	Allowable Stress
Panel Tension F_tA with units of lbs/ft of panel width (kN/m of panel width)		
24/16	7/16” (11 mm)	1,300 (19.0)
48/24	23/32” (18 mm)	2,550 (27.3)
Panel Compression F_cA with units of lbs/ft of panel width (kN/m of panel width)		
24/16	7/16” (11 mm)	2,500 (36.5)
48/24	23/32” (18 mm)	4,300 (62.8)
Panel Shear Through-The-Thickness F_vt_v with units of lbs/ft of shear-resisting panel length (kN/m of shear-resisting panel length)*		
24/16	7/16” (11 mm)	1,980 (28.9)
48/16	23/32” (18 mm)	2,640 (38.5)

*The original table in the Manual for Engineered Wood Construction used units of lbs/in for the Panel Shear Through-The-Thickness table. These values were converted to lbs/ft for consistency.

Table 5-1 Strength Characteristics for OSB Gussets.

Chapter 10 – Volume Ceiling Changes:

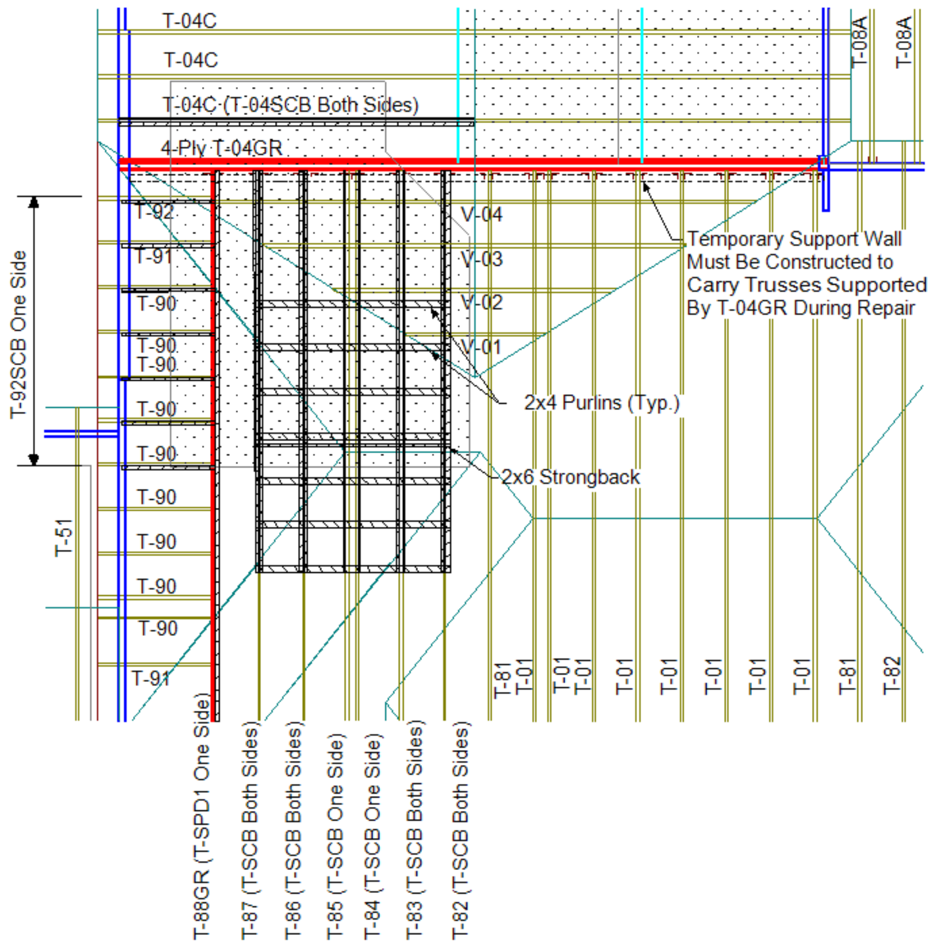
This chapter covers modifications to the bottom chord of the truss to achieve a different ceiling profile. The complexity of repairs can vary greatly from trimming one member to a substantial change in a large number of trusses. Sometimes, the repairs can be handled by simply adding new members with OSB gussets and then cutting out the parts of the truss that are no longer needed. However, often, the OSB gussets are either not large enough to develop the required connection or the time and complexity involved is such that building new trusses or new truss pieces becomes the optimal choice.

This chapter will present two concepts in the repair design that are very useful for ceiling modifications: the scab truss and the spider truss. A scab truss is usually a smaller pre-manufactured truss designed to work with the original truss to complete the structural function while displaying a revised ceiling condition. The spider truss is also a pre-manufactured truss that is shipped in halves or thirds to make for easy installation and once installed, the spider truss spans from one bearing to another and almost completely replaces the structural function of the original truss. The main drawback for these repair trusses is that they have to be built and shipped from the truss manufacturer which can cost the builder several days in the completion of the structure.

Volume ceiling modifications are most often caused by design errors or a lack of communication at the design or sales phase. The volume ceiling may not have been properly called out in the plans. There may have been a change that was not properly communicated to the design team. There may have been some confusion as to whether the volume ceiling was a standard feature for a community or if it was an option. The issue is often realized after the trusses have been installed, which complicates the correction.

The examples that follow came from a hip style house where the tray ceiling option was missed and where nearly every truss in the region of the tray ceiling was different. The repair involved one 4-ply girder, one hip girder, several hip trusses, and several small mono trusses or jacks. The repair required the manufacture of a shorter 4-ply girder, a spider truss, and several scab trusses. A partial truss placement plan was developed to show the location of the each of the repair trusses as shown on the next page along with an index of the examples that follow.

KEY PLAN

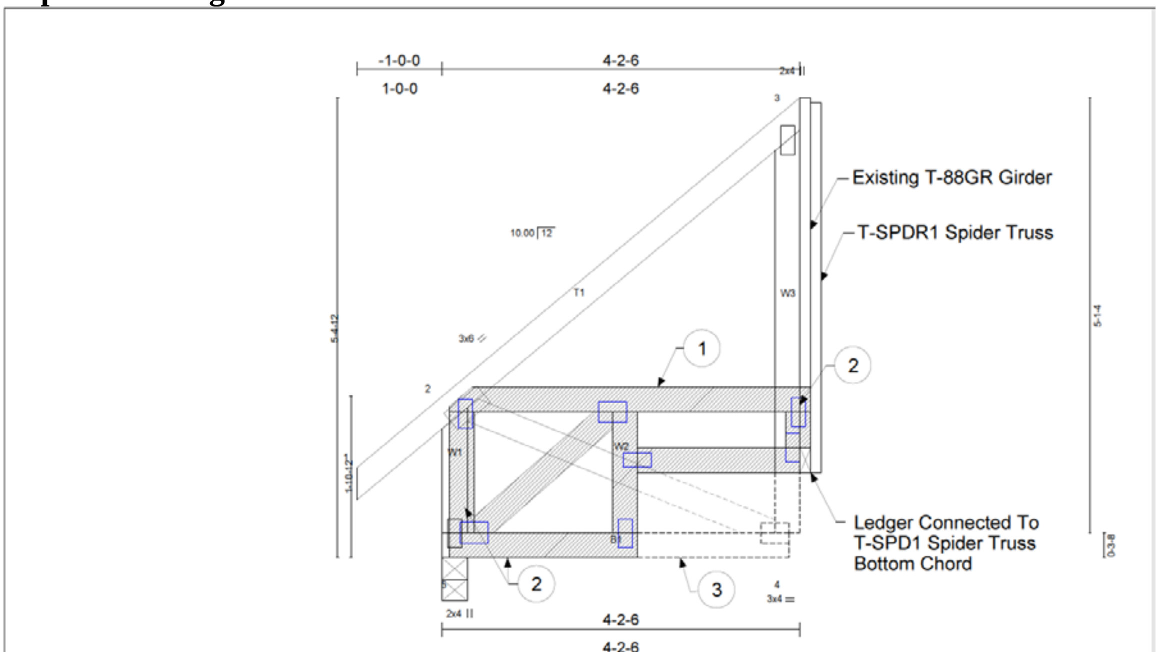


Example	Trusses	Repair
10-1	T-90	Small Scab Truss
10-2	T-82 to T-87	Scab Truss Design Method 1 (Truss Sections)
10-3	T-04C	Scab Truss Design Method 2 (Truss Model)
10-4	T-88GR	Spider Truss
10-5	T-04GR	T-04GR - Girder Truss Replacement

Example 10-1 Small Scab Truss

Problem
A box ceiling profile is to be added to a small jack truss

Repair Drawing



1) Fabricate (1) T-92SCB scab truss for each truss to be repaired.
2) Attach scab truss to open face of existing truss using 10d nails 3" O.C. in all aligning members.
3) Sections of existing truss may be cut out to form box ceiling ONLY after all of the above repair steps have been performed.

Discussion

Of the trusses that were to be repaired, this one was the simplest. Since this truss is short and the forces in the members are low, the main limiting factor in this repair is simply to create the required profile. This truss could have been repaired by cutting the existing members and adding new members using OSB gussets as connectors, but since other larger repair trusses were to be fabricated and shipped to the jobsite, these small jack trusses were also included to decrease the construction time at the job site. The scab truss installation provides a much quicker resolution for this series of trusses than cutting the individual pieces and installing OSB gussets. The scab truss was designed to work with the T-90, T-91, and T-92 jack truss designs.

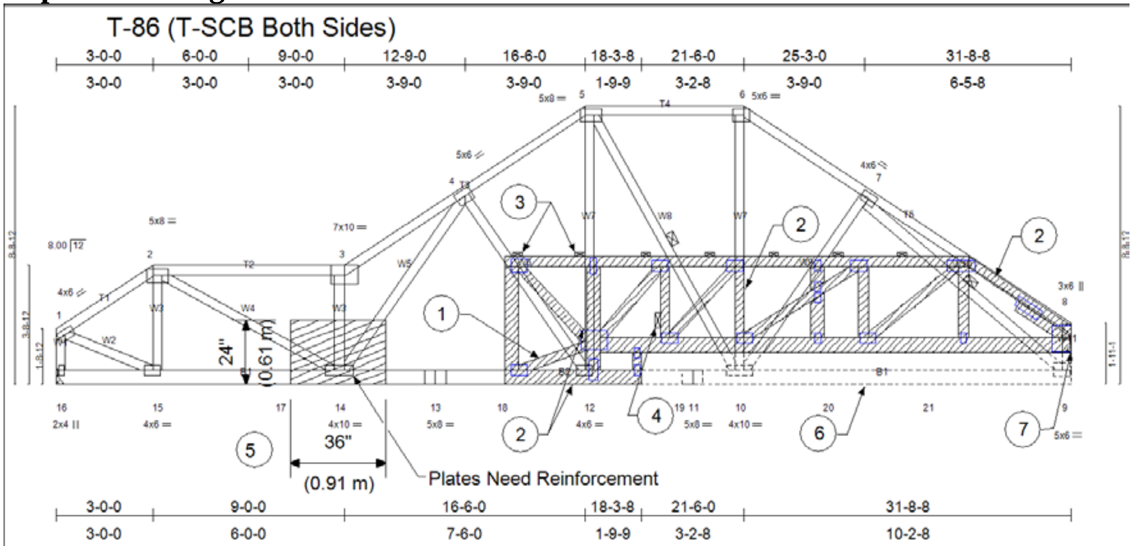
The geometric constraint of installing the truss between existing walls and trusses is an important consideration for this scab truss design. The shortest practical height was chosen along with a reduced horizontal dimension enabling the truss to be installed in the tight space. The completed repair is shown in the photograph in Example 10-4.

Example 10-2 Scab Truss Design Method 1 (Truss Sections)

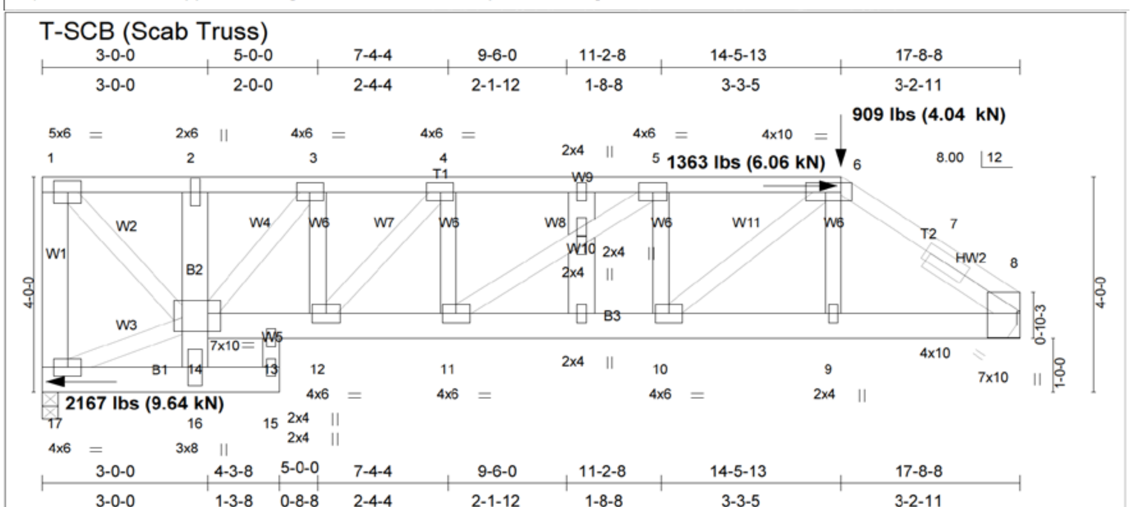
Problem

A box ceiling profile is to be added to a series of hip trusses

Repair Drawing



1) Fabricate 2 scab trusses for each truss to be repaired. See attached sheet T-SCB for fabrication details.
2) Attach scab truss to each face of existing truss using 10d nails (1 row for 2x4 (38 x 89 mm), 2 rows for 2x6 (38 x 140 mm)) 3" (76 mm) O.C. in all aligning members.
3) Install 2x4 (38 x 89 mm) purlins along top chord of scab truss at 2'-0" (0.61 m) O.C.
4) Install 2x6 (38 x 140 mm) strongback at location shown. Connect strongback to each T-SCB scab truss using (3) 10d nails.
5) Apply 24" x 36" x 7/16" (0.61m x 0.91m x 11mm) OSB gussets (APA rated sheathing 24/16 exposure 1) cut as shown to both sides of truss using 10d nails 3" (76 mm) O.C. (1 row for 2x4 (38 x 89 mm), 2 rows for 2x6 (38 x 140 mm)) in all members covered, driven through and clinched.
6) Sections of existing truss may be cut out to form box ceiling ONLY after all of the above repair steps have been performed.
7) Truss is to be supported using USP THDH26-3 or equivalent hanger.

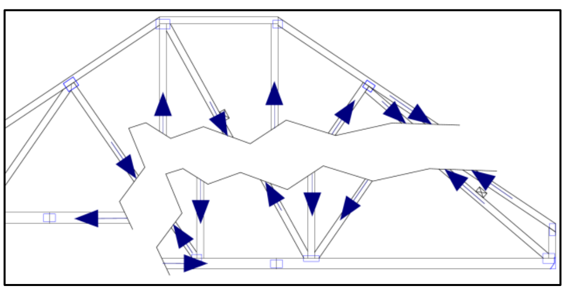


LOAD CASE(S) Standard
1) Regular: Lumber Increase=1.15, Plate Increase=1.15
Uniform Loads (plf)
Vert: 16-17=-106(F=-86), 15-16=-106(F=-86), 13-14=-86(F), 8-13=-106(F=-86), 6-8=-74, 1-6=-74
Concentrated Loads (lb)
Vert: 6=-909(F)
Horz: 6=1363(F), 17=-2167(F)

Discussion

There are two main methods for designing a scab truss. For the purposes of this course, Method 1 will be described as the Truss Sections Method and Method 2 will be called Truss Model Method. The Truss Model Method will be discussed in greater detail in the next example (10-3). Both methods have their advantages and disadvantages and often it is the repair designer's preference and training that is the determining factor as to which method to use.

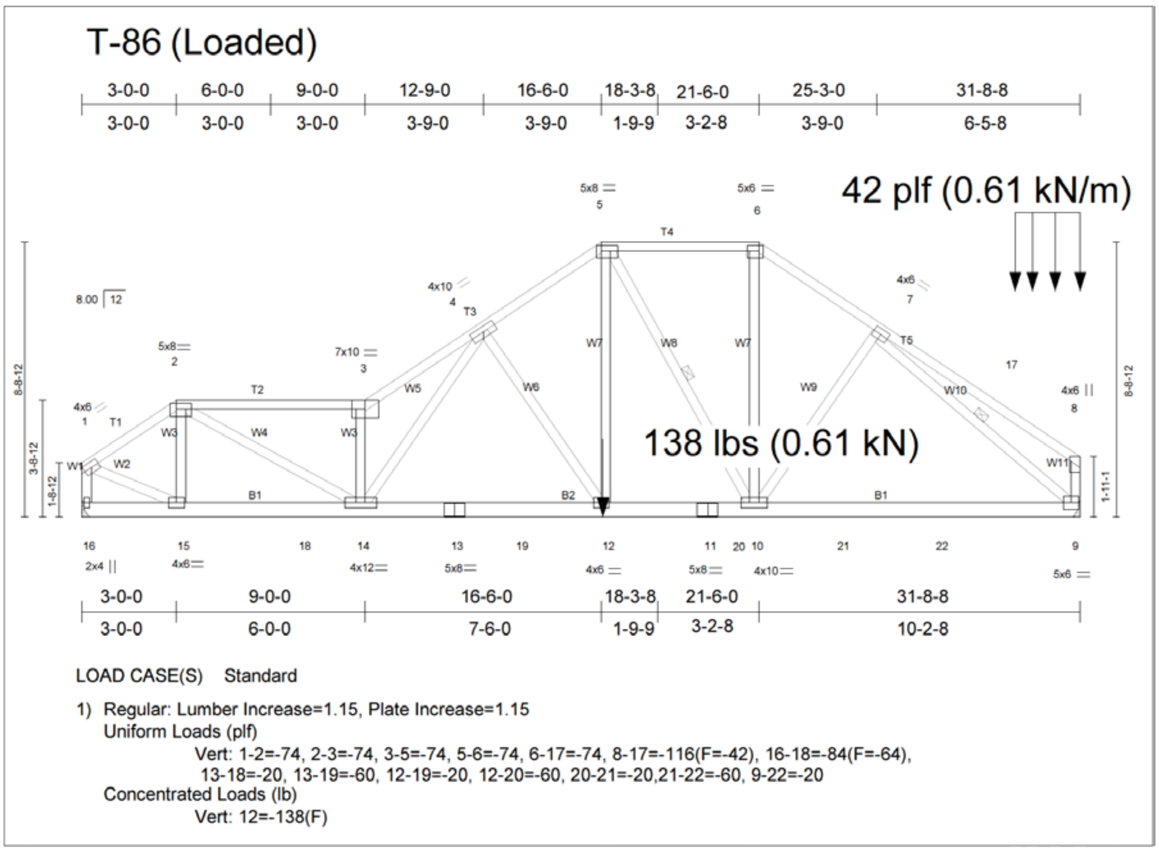
The first step for both methods is to determine a general size and shape for the scab truss. Since much of the scab truss is not constrained by the roof planes, there is some flexibility in forming the profile of the scab truss to best fit the situation. The scab truss must, at a minimum, encompass the volume ceiling and overlap enough of the original truss beyond the extents of the volume ceiling to develop the required connections. Other considerations include location of the key webs for connections and clearances to deliver the scab trusses to the repair area. A scab truss that is to be installed after the trusses are in place typically has a maximum height of 6'-8" (2.02 m) so that it can pass through a standard door opening. The height of the scab truss in this example was set at 4' (1.22 m) providing sufficient top chord connection and allowing access through a window opening.

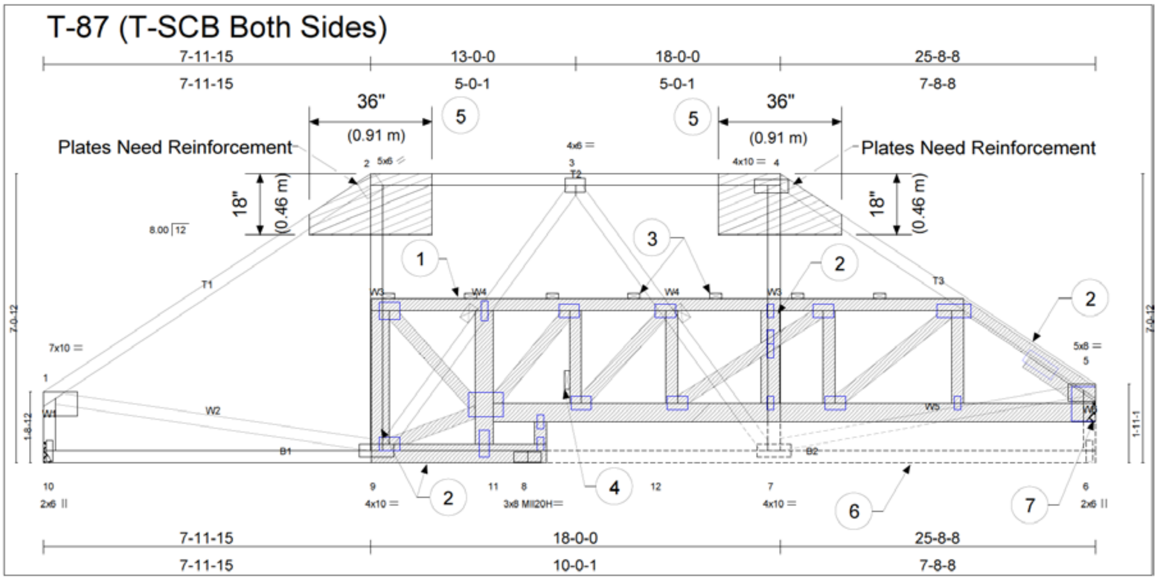


The Truss Sections Method effectively divides the original truss in two pieces or sections with the dividing lines being the perimeter of the scab truss. A free body diagram can be developed showing forces in each of the members along the split as shown in the diagram to the left. The key concept with the Truss Sections method is that some of these forces are applied to the scab truss to make the scab truss behave like it is part of a larger truss. By adding extra forces, the plates and lumber are sized for the larger truss rather than only for the length of the scab truss. Designer discretion is required since a lot of the webs with the forces shown will be cut to make the volume ceiling and the original truss has multiple load cases generating many possible force combination in each member. Experience has shown that the most critical scab truss forces are the maximum bottom chord tension force and the maximum top chord compressive force. The diagonal web that is nearly parallel to the top chord contains the largest compressive force in this example. However, that web with the large compressive force will also be cut, so the force is projected into the top chord member. The forces that were applied forces to the scab truss include a 2167 lbs (0.64 kN) load in tension on the bottom chord and the resolved forces of 909 lbs (4.04 kN) vertical and 1363 lbs (6.06 kN) horizontal in compression on the top chord are shown on the scab truss design drawing, T-SCB, on the previous page.

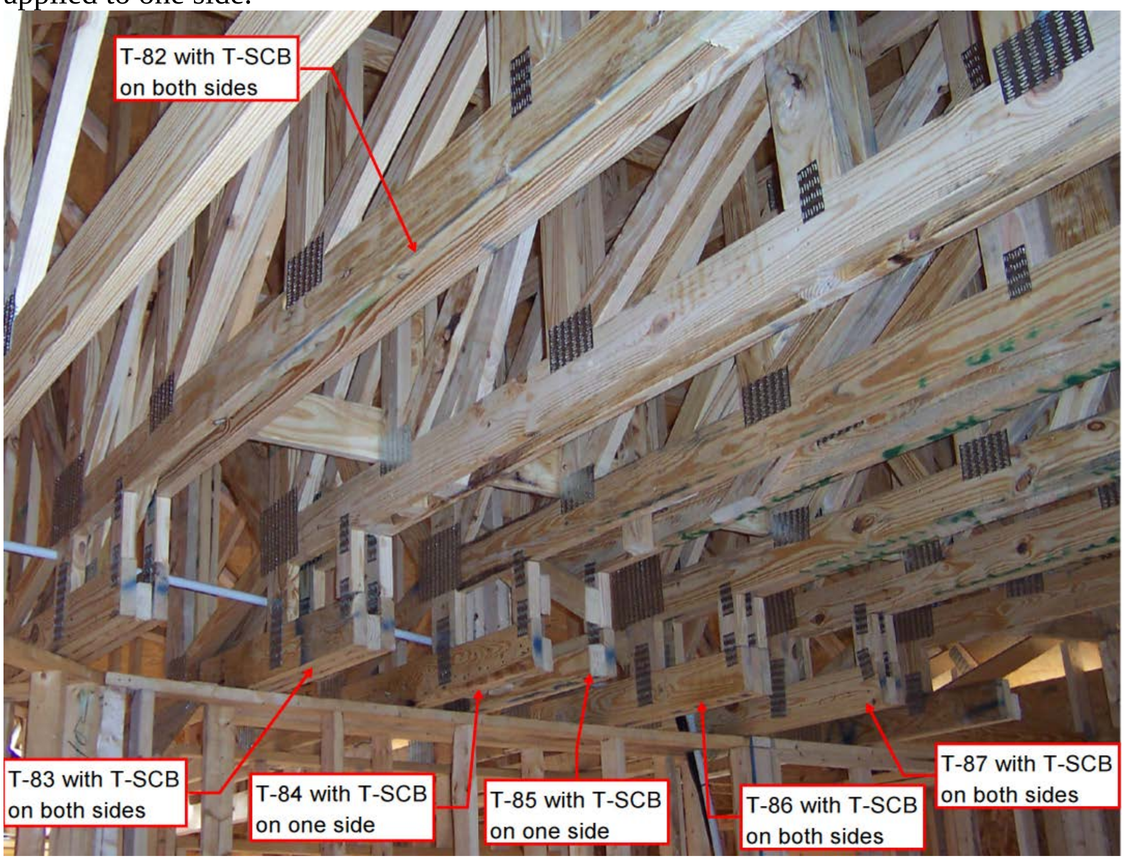
The scab truss is usually formed from the original truss to maximize the number of members lining up. However, in this example, multiple different truss configurations were involved, so verticals where added at key locations in the scab truss to match the vertical webs of each original truss as shown on the T-86 and T-87 repair drawings. It is recommended to lower the top chord of the scab truss by 0.75" (19 mm) from the very top edge of the original truss because the nails from the shingles often protrude through the roof sheathing and sometimes block installation of the scab truss.

The final step for the Truss Sections method is to apply a load back into the original truss to determine if any member or joint needs to be reinforced due to the effects of the scab truss. The weight of each scab truss is 138 lbs (0.61 kN). Since, the scabs are applied to both sides of the original truss, it was decided to apply 138 lbs (0.61 kN) as a concentrated load at the left most aligning vertical web member and a uniform load of 42 plf (0.61 kN/m) based on the weight divided by the overlapping distantce of the top chord members. The extra load caused one more set of plates to be upsized for each of the truss configurations. OSB gussets where added to reinforce these joints.





The following photograph shows the completed repair for the whole series of trusses. It should be noted that due to the proximity of the T-84 and T-85 trusses, the scab truss was only applied to one side.

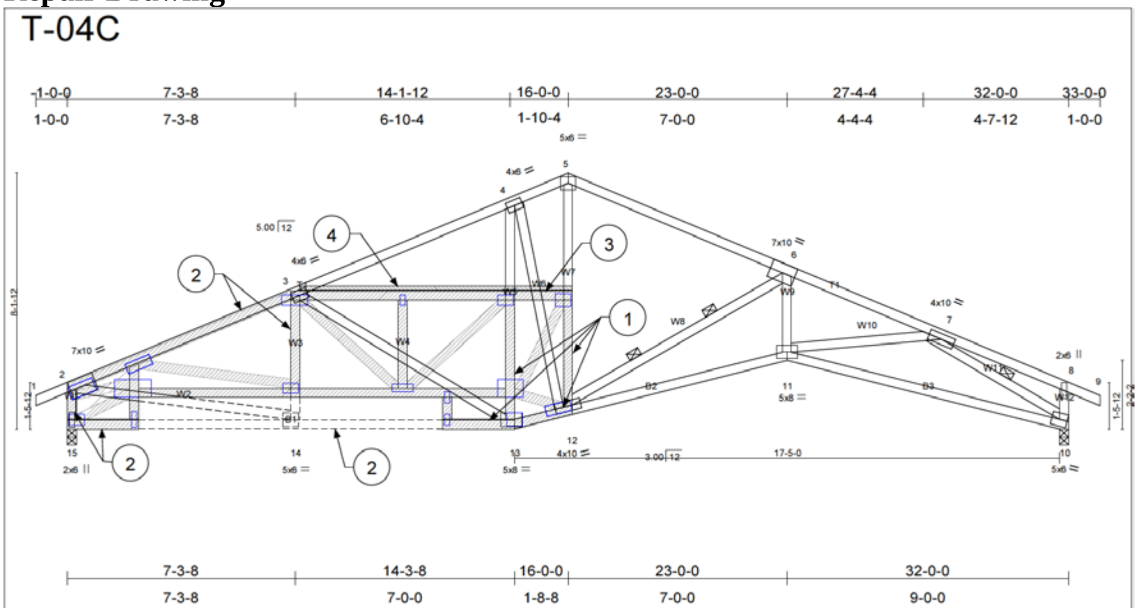


Example 10-3 Scab Truss Design Method 2 (Truss Model)

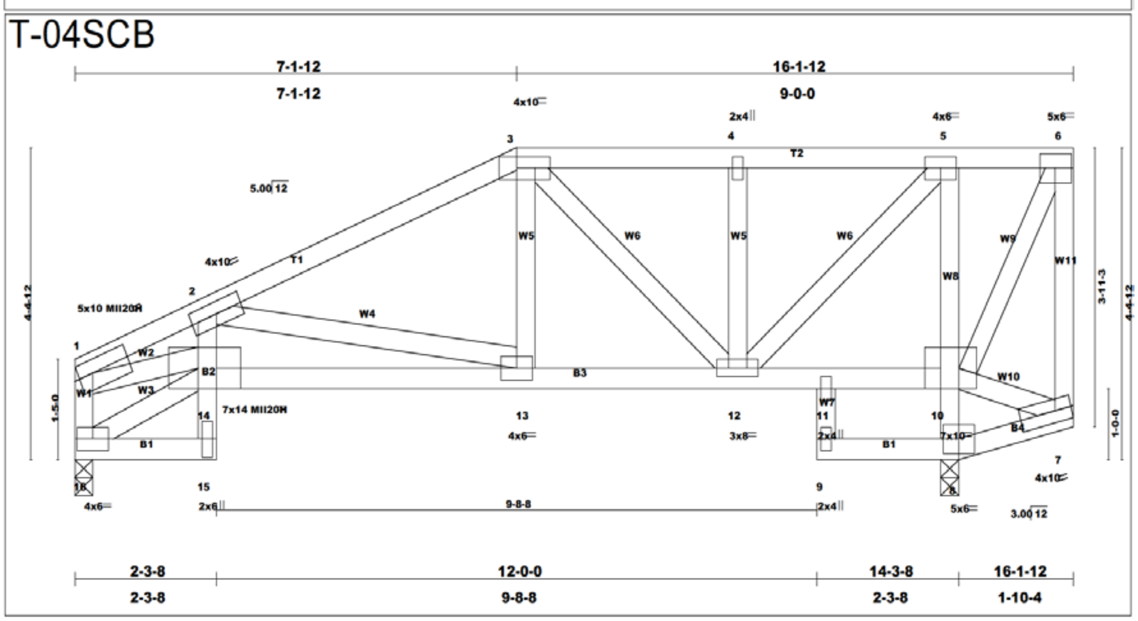
Problem

A box ceiling profile is to be added to a truss

Repair Drawing



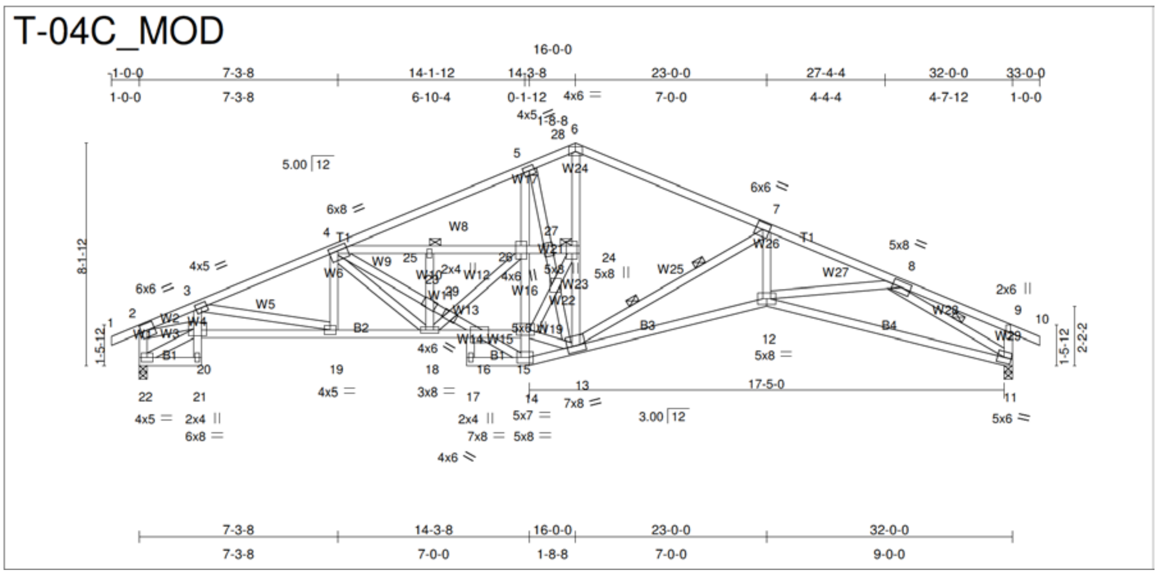
1) Fabricate 2 scab trusses for each truss to be repaired. See attached sheet T-04SCB for fabrication details.
2) Attach scab truss to each face of existing truss using 10d nails 3" (76 mm) O.C. in all aligning members.
3) Attach 2x4 (38 x 89 mm) member to top face of top chord of scab truss to form an L-brace.
4) Sections of existing truss may be cut out to form box ceiling ONLY after all of the above repair steps have been performed.



Discussion

The end result of the Truss Model Method is similar to the Truss Sections Method the previous example in that both methods produce a scab truss for a volume ceiling repair. However, the approach to the design is different.

The first step in the Truss Model Method is to create a composite design using the scab truss as part of the original truss. The composite design for the T-04C is shown below. The thought here is that the new volume ceiling would change the stiffness matrix for the whole truss. This composite design is accomplishing a similar goal of using the loaded truss from the Truss Sections Method in trying to determine any modifications that need to be done to the remaining portion of the truss outside the scab truss region. The analysis showed that the truss plates outside the scab truss area did not need to be reinforced.



The second step in the Truss Model Method is to remove the members of the original truss leaving only what needs to be fabricated as the new scab truss. Once the members are removed, the final step is to manually change the plate sizes back so that the scab truss members have similar coverage on the scab truss as is shown in the composite design T-04C_MOD shown above. The following photograph shows the completed repair.

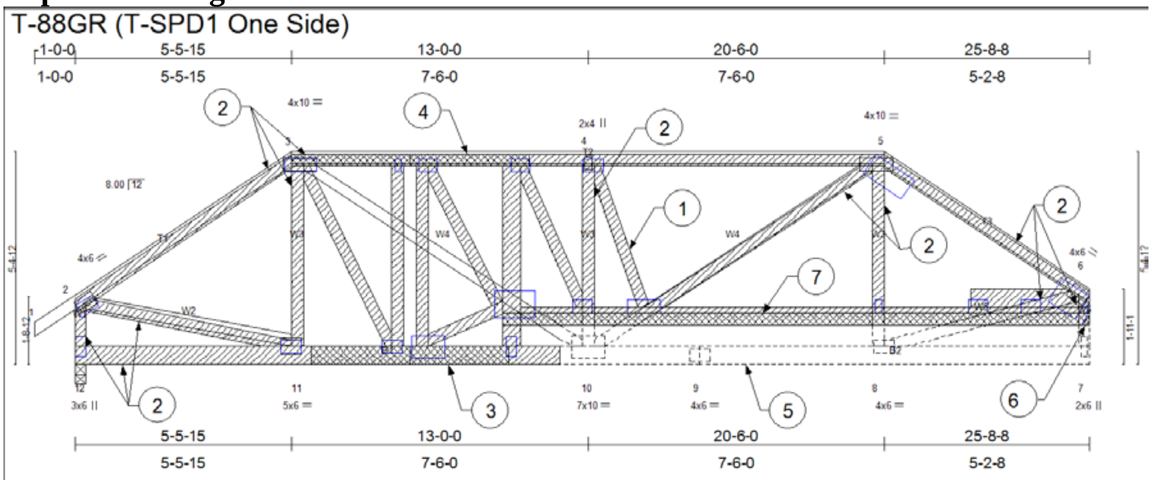
Both the Truss Section method and the Truss Model method have advantages and disadvantages. Both methods produce a scab truss suitable for modifying a truss to produce a volume ceiling. The composite design in Truss Model Method is a better predictor of the behavior of the final repaired truss. However, manually changed plates can sometimes be changed back to their original size by the software prior to manufacture, so it is important for the truss manufacture to have good quality control to use this method. Applying the forces to the scab truss in the Truss Section method allows the scab truss to act like a larger truss even if a user inadvertently recalculates the plates. Another advantage of the Truss Section method is that it is a little easier to fabricate one scab truss design for multiple truss designs whereas the Truss Model Method usually produces one scab truss design per repaired truss. It should be noted that these methods are not exclusive to each other and at the repair designer's discretion both methods could be implemented. The choice between methods or the use of some hybrid combination of the two is ultimately based on the repair designer's preference and training. Either method can produce an effective repair design.

Example 10-4 Spider Truss Repair

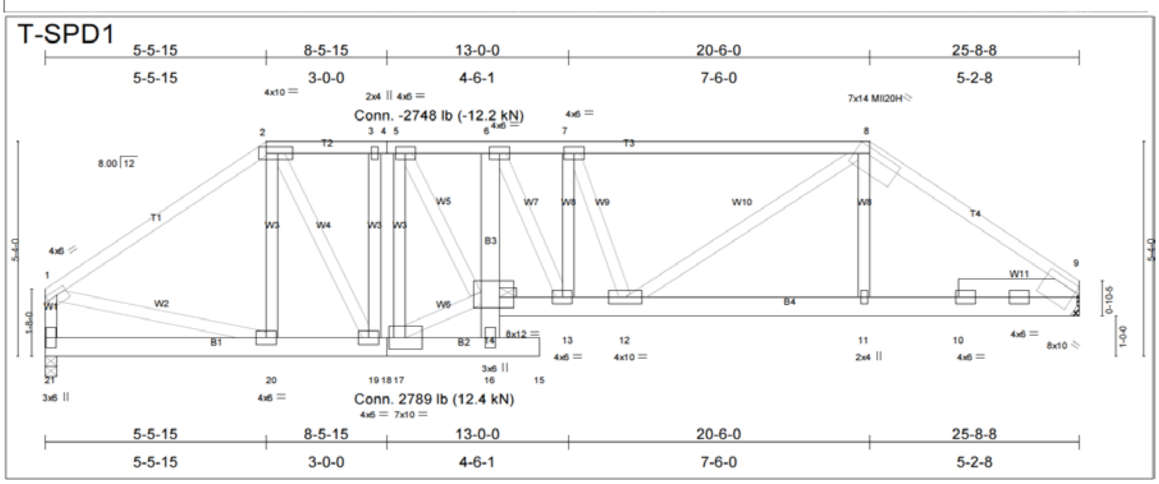
Problem

A box ceiling profile is to be added to a truss

Repair Drawing



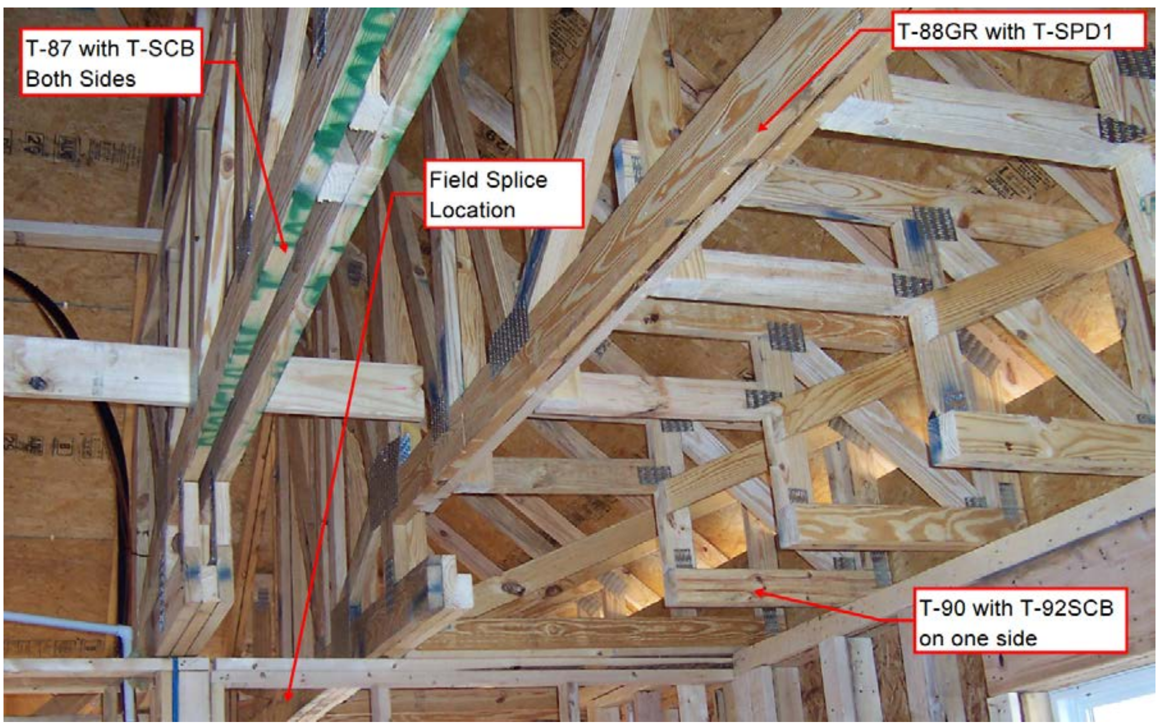
1) Fabricate 1 Spider truss (2 halves) for each truss to be repaired. See attached sheet T-SPD1 for fabrication details.
2) Attach 2 spider truss halves to face of truss using 10d nails (1 row for 2x4 (38 x 89 mm), 2 rows for 2x6 (38 x 140 mm)) 3" (76 mm) O.C. in all aligning members.
3) Install 2 x 6 (38 x 140 mm) #2 SP scab to one side of spider truss bottom chord. Attach scab using construction grade adhesive and 3 rows 10d nails spaced 6" (152 mm) O.C. Scab length = 5' (1.5 m).
4) Install 2 x 4 (38 x 89 mm) #2 SP scab to one side of spider truss top chord. Attach scab using construction grade adhesive and 1 row 10d nails spaced 3" (76 mm) O.C. Scab length = 6' (1.8 m).
5) Sections of existing truss may be cut out to form box ceiling ONLY after all of the above repair steps have been performed. Level cut and remove enough of existing webs to allow 2 x 4 (38 x 89 mm) ledger and supported trusses on back side of spider truss. (4 Locations)
6) Truss is to be supported using USP THD26-2 or equivalent hanger.
7) Install 2 x 4 (38 x 89 mm) #2 SP ledger to spider truss bottom chord within plane of original truss. Attach ledger using 1 row 10d nails spaced 3" (76 mm) O.C.



Discussion

Unlike the scab truss designs of the previous examples where the new truss worked with the old truss to accomplish the structural goal, the spider truss design completely replaces the structural function of the base truss. The spider truss is a good alternative to the scab truss when the volume ceiling modification encompasses a significant percentage of the truss span. In order to install a full span truss in a structure with the roof already in place, multiple pieces must be fabricated requiring field splice connections. The truss software is capable of identifying the field splice connections and specifying the required connection capacity.

The best location for the field splice of this spider truss was approximately 8.5' (2.59 m) from the left end. At that location, the top and bottom chord members of the original T-88GR could serve as scabs on one side for the field splice connection. The base truss already in place actually aids in the installation of the two piece spider truss by providing structure to support it until the pieces can be connected together. After the pieces are attached to the base truss, then the lumber scabs should be applied to complete the splice connection. Once the field splice connection is complete, the volume ceiling may be cut out of the base truss. A 2-ply truss hanger was chosen as the connection to the T-04GR. Finally, a connection was needed to attach the T-90, T-91, T-92 trusses with the T-92scb. A 2 x 4 (38 x 89 mm) ledger was installed within the plane of the original T-88GR requiring web members be cut further back. Note that the T-92scb was designed with a pocket in the right end of the truss for the ledger. The following photo shows the T-88GR with T-SPD1 spider truss along with the supported T-90 trusses with the T-92SCB.



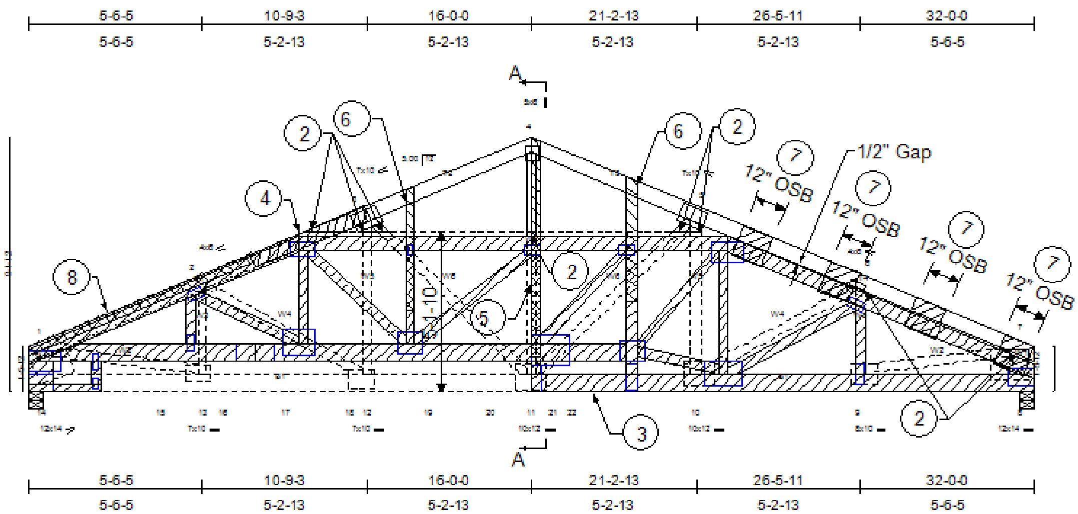
Example 10-5 Girder Truss Replacement

Problem

A box ceiling profile is to be added to a truss

Repair Drawing

T-04GR with T-04REPL

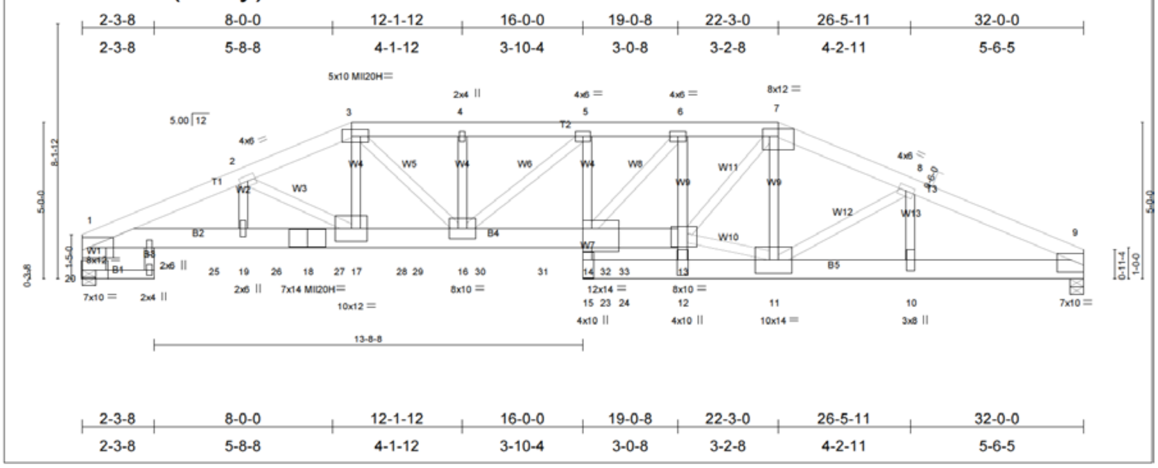


1) Before beginning repair of girder, construct a temporary support wall to carry trusses supported by T-04GR during repair. At this time, existing hanger fasteners and bolts may be removed (bolts should be reinstalled in T-04REPL when complete).
2) Cut out and remove area of existing T-04GR girder as shown to allow installation of T-04REPL truss.
3) Install T-04REPL repair truss (See Sheet T-04REPL for fabrication details). Truss is to be installed one ply at a time and connected using the following nailing patterns: connect top chord plies using 2 rows 10d nails spaced 6" (152 mm) O.C., connect bottom chord plies using 4 rows 10d nails spaced 4" (102 mm) O.C., and connect webs using 1 row 10d nails spaced 9" (229 mm) O.C. All chords to be connected using 1/2" (13 mm) diameter bolts (ASTM a-307) with washers (removed from T-04GR at Step 1) spaced 2' (0.61 m) O.C.
4) Install 2 x 6 (38 x 140 mm) #2 SP scabs to both sides of top chord member. Attach scabs using 3 rows 10d nails spaced 6" (152 mm) O.C. Scab length = 4' (1.22 m).
5) Install 2 x 4 (38 x 89 mm) #2 SP scabs to both sides of truss connecting T-04REPL vertical to remianing T-04GR top chord. Attach scabs using 10d nails spaced 3" (76 mm) O.C. Scab length = 7' (2.13 m).
6) Install 2 x 4 (38 x 89 mm) #2 SP scabs to both sides of truss connecting T-04REPL vertical to remianing T-04GR top chord. Attach scabs using 10d nails spaced 3" (76 mm) O.C. Scab length = 4' (1.22 m). (2 Locations)
7) Apply 12" x 12" x 7/16" (0.30 m x 0.30 m x 11 mm) OSB gussets (APA rated sheathing 24/16 exposure 1) cut as shown to both sides of truss using 2 rows 10d nails 3" (76 mm) O.C. in all members covered. Gussets are to be spaced at 36" (0.91 m) O.C. (4 Locations) An approximate 1/2" (13 mm) gap should remain between top chord of T-04GR and T-04REPL.
8) Install 2 x 4 (38 x 89 mm) #2 SP or SPF scab to one side of top chord to match roof plane. Attach scab using 10d nails spaced 3" (76 mm) O.C.

Discussion

The scab and spider truss concepts work well for single ply and occasionally 2-ply trusses, but using those methods on 3 or more ply trusses usually are not effective due to the larger forces in multiple ply trusses. Example 11-9 presents an example of a multiple ply spider truss, but for this example there was no cost effective way to incorporate the volume ceiling for the 4-ply T-04GR truss while still in place. One option was to cut a hole in roof and slide in a new girder truss using a crane. At the time of the repair, the shingles had already been installed, so it was decided to work from within the building and not disturb the roofing.

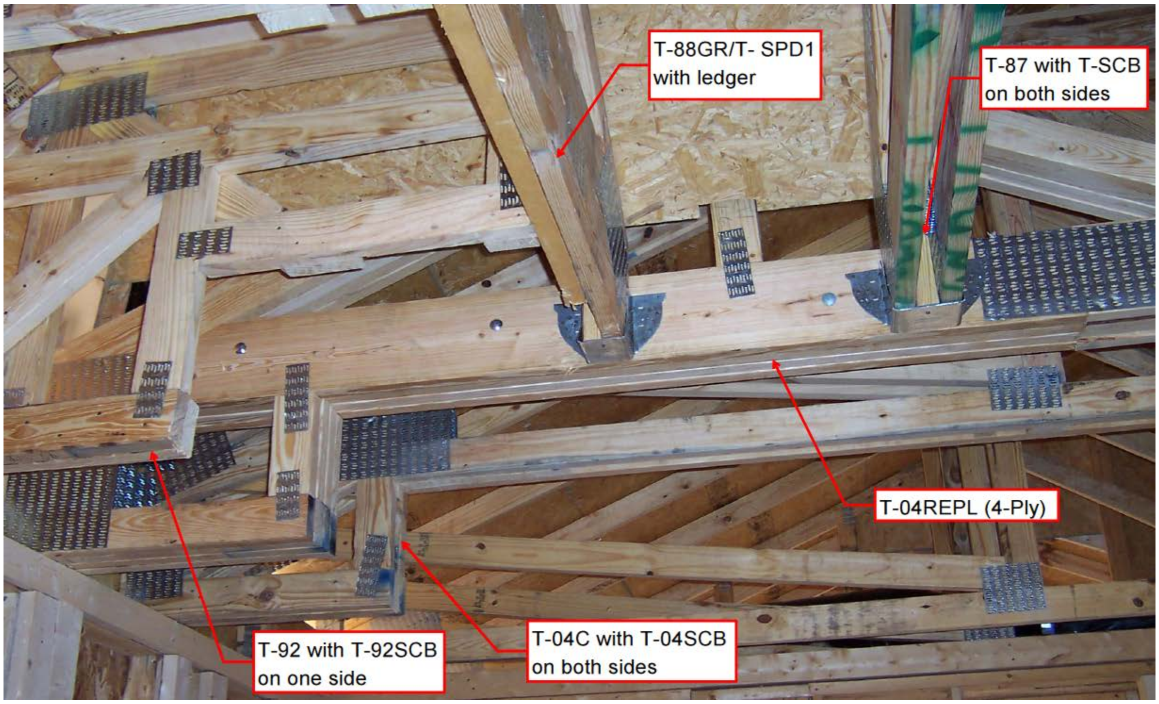
T-04REPL (4-Ply)

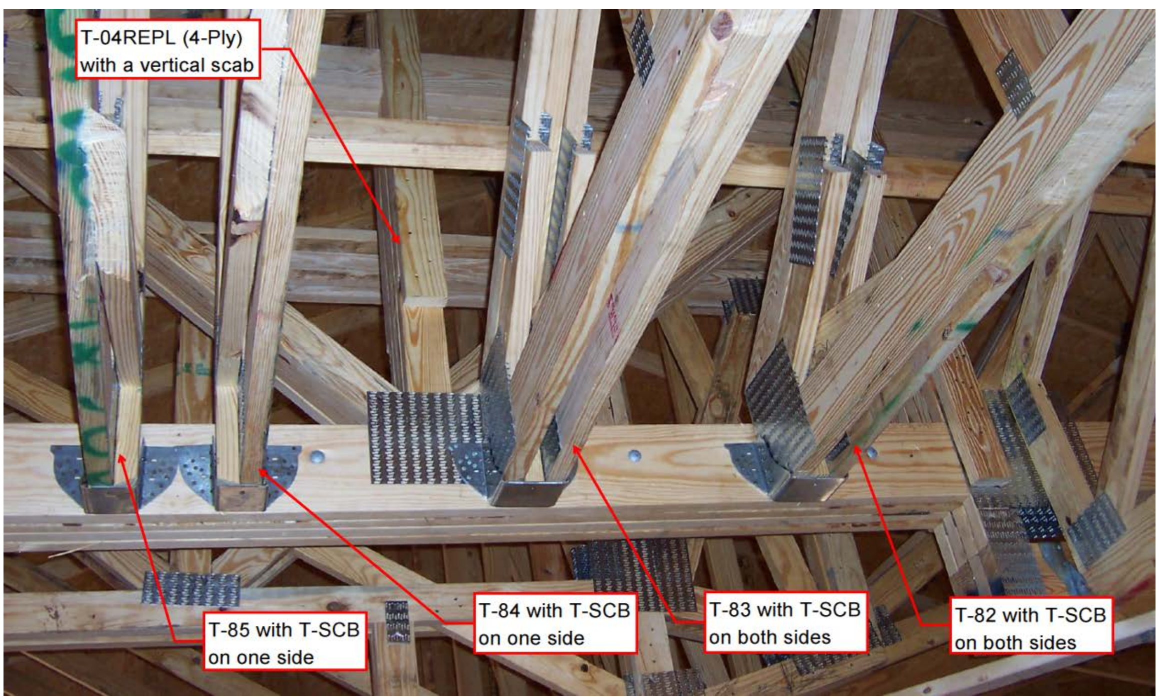


A new girder truss was designed to support the required load and the height was set to allow it to be inserted through a nearby window opening. The T-04REPL truss was designed with a lower heel height than the original T-04GR on the right end so that the new top chord would fit completely under the existing top chord thereby maintaining most of the connection to the sheathing.

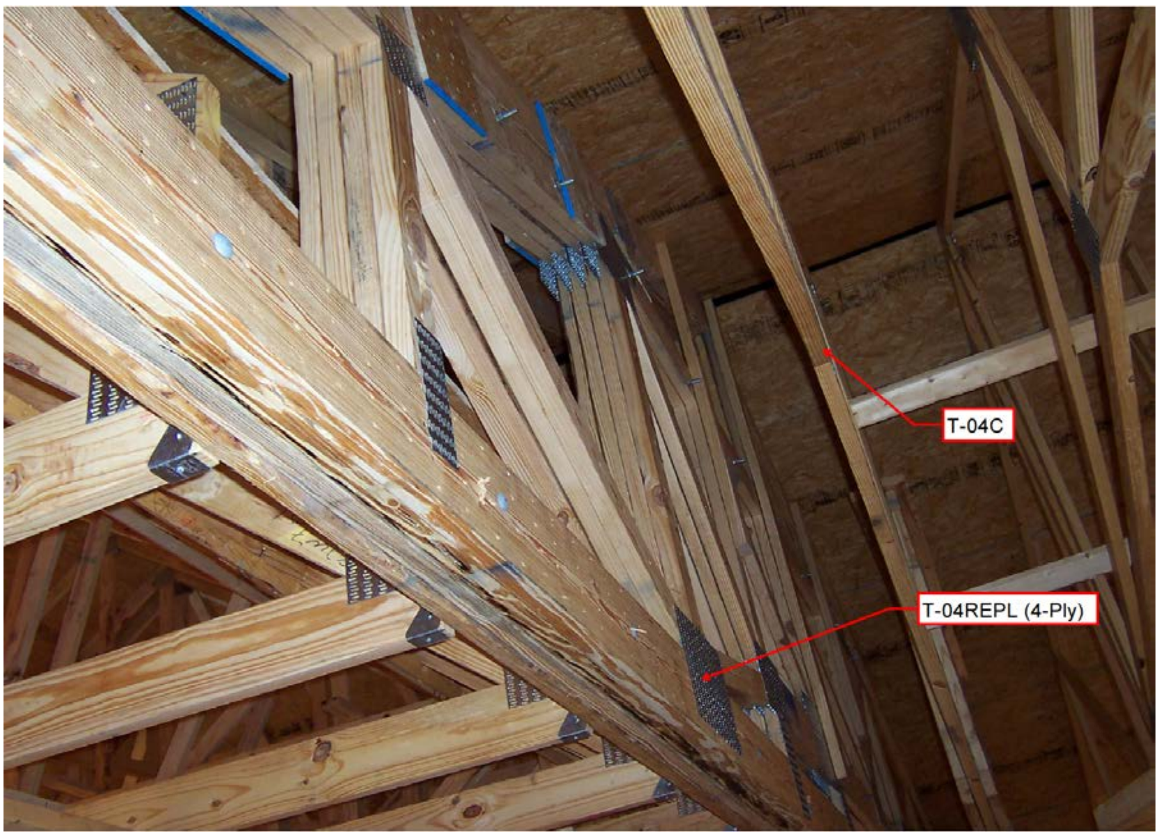
A temporary wall or support system is often required to provide support for the structure while the girder is being repaired. Once the temporary wall was constructed and the necessary portions of the original T-04GR were removed, one ply at a time of the T-04REPL was brought in through the window opening, installed, and connected to the previous ply. Connections were then made along the top chord of the T-04REPL to the remaining portions of the T-04GR. These connections included 2 x 6 (38 x 140 mm) scabs along the left sloping top chord, 2 x 4 (38 x 89 mm) vertical scabs along the flat region, and OSB gussets along the right sloping top chord. These connections provided the necessary bracing for the top chord of the T-04REPL and the structural continuity of the system.

The following photographs show the completed replacement of the T-04GR with the T-04REPL along with the surrounding repairs.


T-88GR/T- SPD1
with ledger
T-87 with T-SCB
on both sides
T-04REPL (4-Ply)
T-92 with T-92SCB
on one side
T-04C with T-04SCB
on both sides


T-04REPL (4-Ply)
with a vertical scab
T-85 with T-SCB
on one side
T-84 with T-SCB
on one side
T-83 with T-SCB
on both sides
T-82 with T-SCB
on both sides


T-04C
T-04REPL (4-PLY)


T-04C
T-04REPL (4-Ply)

Chapter 11 – Girder Truss and Truss Loading Modification Repairs:

Building on the previous chapter involving volume ceiling changes, this chapter addresses the complexities of modifications or reinforcements to multiple ply girder or other trusses with changes in the design loads. Multiple ply girder trusses involve additional variables such as: the trusses, beams, or other framing members being supported on one or both sides, the high forces in the members, and the extra thickness of the trusses. Therefore unique solutions are often required.

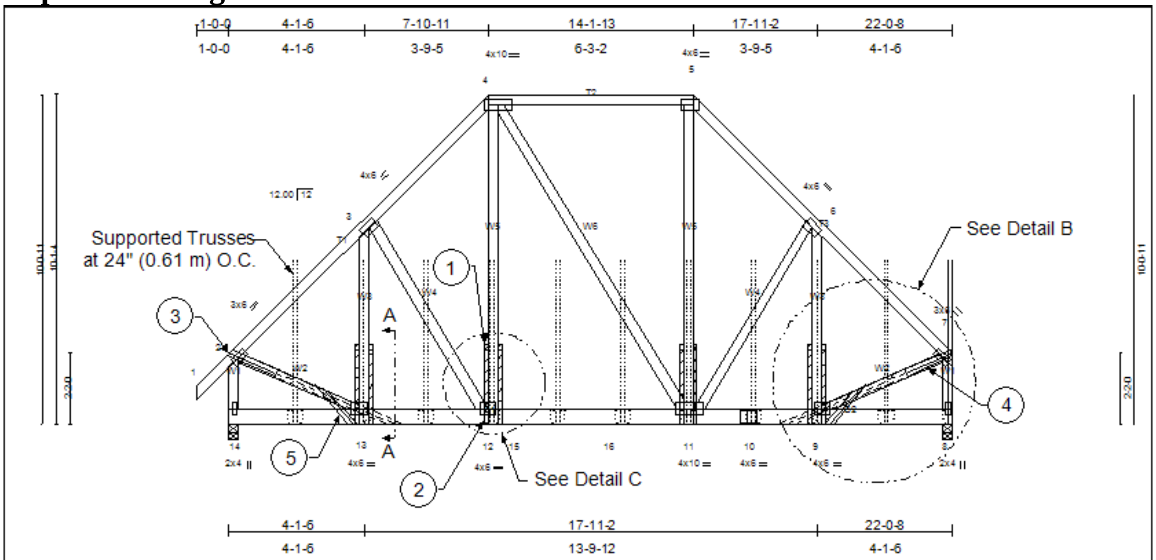
There is no standard approach for complex girder truss repairs, but it is important to gather as much information as possible about the truss that needs to be modified including the location of supported trusses, the bearing walls, the size of the members, and access to the truss to allow material delivery and repair crew work. Sometimes, a new unclaimed bearing wall either in the girder truss or the supporting truss can significantly influence the required repair. A simple unique repair solution may be more cost effective than replacing the entire girder truss, but at times, replacement of all or part of the girder will be required.

The examples provided in this chapter are mostly unique girder truss or truss loading repairs that were designed for a specific set of circumstances and may not work for other girder truss repairs. However, these examples are provided to spark ideas for solving complex problems involving multiple ply girder or other trusses requiring a change in loading.

Example 11-1 Under Loaded Girder Truss 1

Problem
A 4-ply girder truss was shipped, but the design had no extra design load for the supported trusses.

Repair Drawing



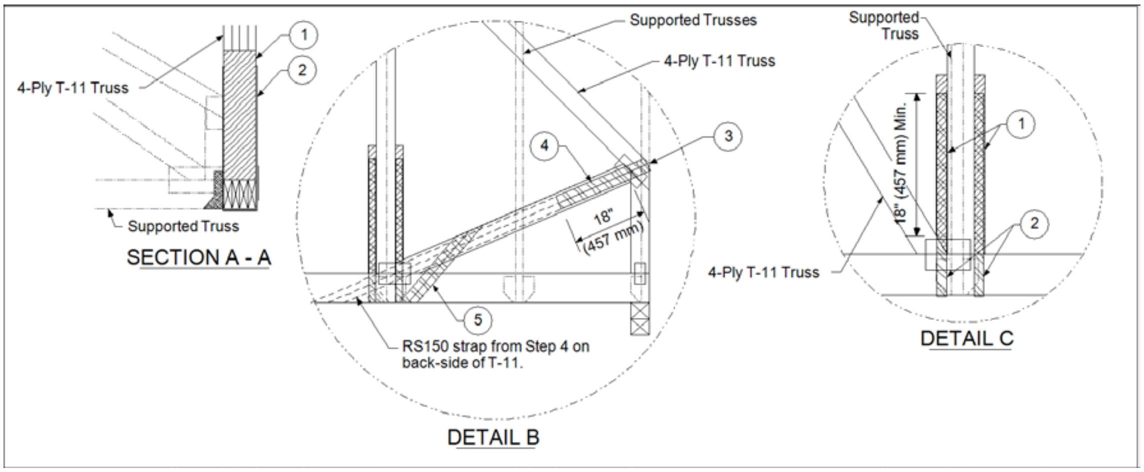
Conditions: Truss was underloaded.

1) Install 2 x 8 (38 x 184 mm) No. 2 SP blocks ripped to 6" (152 mm) width to both sides of all inner vertical web members as shown (see Section A - A and Detail C). Attach blocks using 1 row 16d nails 6" (152 mm) O.C. into each ply covered. Blocks are not required if full nailing for the USP RS150 or equivalent strap can be developed in truss vertical web. Block length = 2' (8 Locations)
2) Install USP RS150 or equivalent strap to either 2 x 8 (38 x 184 mm) block or to the truss vertical, wrap around bottom chord, and up the opposite side (see Section A - A and Detail C). Fill all nail holes with 8d nails except the bottom face of the bottom chord and locations where strap overlap existing truss hangers. Bottom face of bottom chord may be notched for flush installation of strap. Approximate Strap Length = 5' (1.5 m) (8 Locations).
3) Notch top face of top chord to allow square wrapping of (2) USP RS150 or equivalent straps side-by-side. (2 Locations)
4) Install (2) USP RS150 or equivalent straps side-by-side to supporting face of diagonal web (ensuring a minimum 18" (457 mm) of nailing is available) wrapping over the notch in the top chord down the full length of the web as shown (see Detail B). Strap shall continue to bottom face of bottom chord. Approximate Strap Length = 9' (2.7 m) . (2 Locations)
5) Install (2) USP RS150 or equivalent straps side-by-side to the top face of the diagonal web member wrapping to supporting face of truss angled as shown to miss supported truss and hanger (see Detail B). Straps shall wrap around bottom face of bottom chord to opposite side, ending at strap installed in step 4. Approximate Strap Length = 3.5' (1.1 m). (2 Locations)

Discussion

This 4-ply truss was released to be fabricated and shipped without any girder loads for the supporting trusses despite rigorous checking procedures in place. This design department error was not caught until the frame stage of construction. However, the girder loads had at one time during the design process been applied to the truss and then were 'lost' while refining the design or implementing a change order. This was evident because several members had been manually upgraded to a stronger grade of lumber so only the truss plates at joints 2, 7, 9, 11, 12, & 13 required changes because of the additional loading.

The first decision to make in a situation like this is truss replacement vs reinforcement/ repair and since only a few plates changed, repair was the better solution. When a multiple ply truss is fabricated, truss plates are placed on both sides of each ply, so in this case where a 4-ply truss was involved, there are 8 faces for attaching the truss members. However, once the truss is installed only 2 faces are available for the repair. Even then one face is severely limited because of the hangers and supported trusses located along the length of the girder. Metal strapping can reinforce the original truss plates because it can develop the connection in less space than lumber scabs and it can wrap around the wood members. However, metal strapping can only be used in tension applications since it has no rating for use in compression.



The 16 gauge (1.52 mm) x 1 1/4" (32 mm) coil strap was specified because of its availability and flexibility. Since the product comes in a coil, the strap can be cut to the needed length and the thickness of the strap allows it to be bent around each lumber edge. Other similar straps could have worked in this repair as well, but the coil strap provided a good option because of the various custom lengths required in this repair. The distance that the strap wrapped around each member exceed the End Length provided in the literature.

Vertical blocks were necessary because the supported trusses were located exactly at the vertical web members. The scabs allowed the straps to wrap from the front face to the back face of the girder on both sides of the supported truss at the verticals. This wrapping creates a positive connection between the web and chord members where all four plies resist the dominant tension forces. The use of 8d (0.131" / 3.33 mm) nails is recommended in the metal strapping. These nails are 2 1/2" (64 mm) long. The nails through the strap on the front face would reach into the first two plies, while nails through the strap on the back face would reach the 3rd and 4th plies.

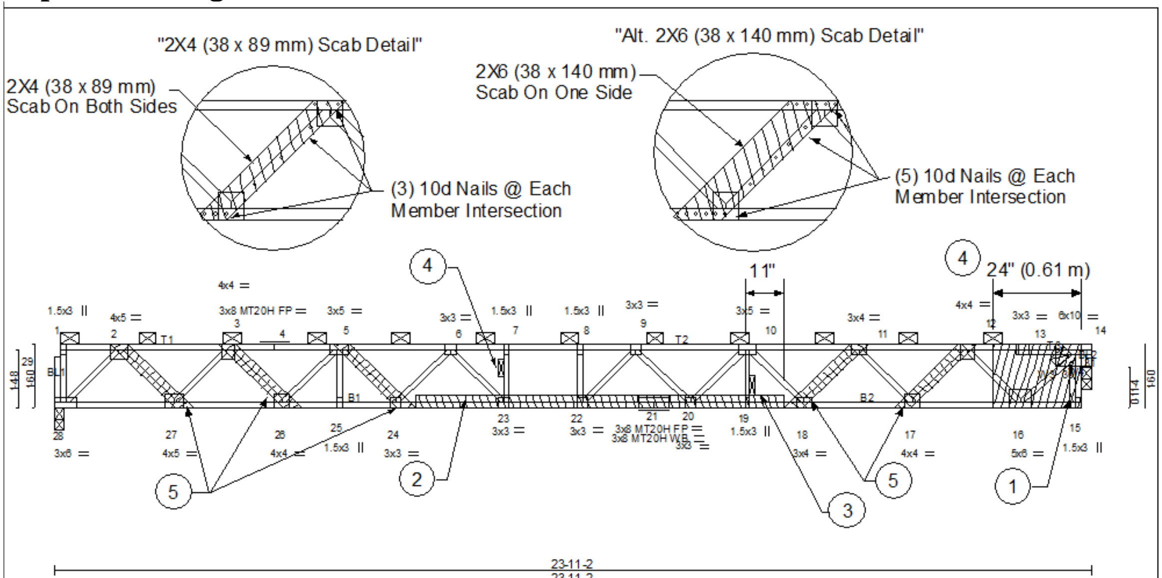
Vertical straps around the bottom chord was an ideal solution for this repair. However, cutting notches in the top chord to make the straps wrap straight around to the back side proved to be more difficult than anticipated. In retrospect, it would have been better to reinforce the top chord joints 2 and 7 with OSB gussets applied to the opposite face of the girder from the supported trusses and sized for the application with 6" (152 mm) long structural screws for the connection.

Example 11-2 Under Loaded Trusses for a Large Building

Problem

Numerous trusses were under designed when an insufficient top chord dead load was used in the job defaults.

Repair Drawing



Conditions: Truss to be loaded for green roof

REPAIR NOTES:
1) Install 2 x 4 (38 x 89 mm) #2 SP vertical block cut to fit below existing diagonal web. Cut for tight fit with full wood-to-wood contact.
2) Install 2 x 4 (38 x 89 mm) SS SP scabs to both sides of truss using 10d nails @ 4" (102 mm) O.C. in all members covered.
Scab Length = 8'-6" (2.6 m).
3) Thread 2 x 6 (38 x 140 mm) strongback through truss as shown. Attach using (3) 10d nails in each truss. (2 Locations)
4) Apply 18" x 24" x 23/32" (0.46 m x 0.61 m x 18 mm) OSB gussets (APA rated sheathing 48/24 exposure 1) to both sides of truss using 10d nails 4" (102 mm) O.C. in all members covered.
5) Install 2 x 4 (38 x 89 mm) #2 SP scabs to both sides of truss using (3) 10d nails at each member intersection. Scab Length = 29" (0.74 m). (5 Locations)
***NOTE: Scabs may be installed flush to either side of web as needed to allow clearance for interfering wires \ pipes.

***NOTE: If diagonal scabs can not be applied to both sides of truss use alternative procedure below:
5) Install 2 x 6 (38 x 140 mm) #2 SP scab to open side of truss using (5) 10d nails at each member Intersection. Scab Length = 29" (0.74 m). (5 Locations)
***NOTE: Scab may be installed flush to either side of web as needed to allow clearance for interfering wires \ pipes.

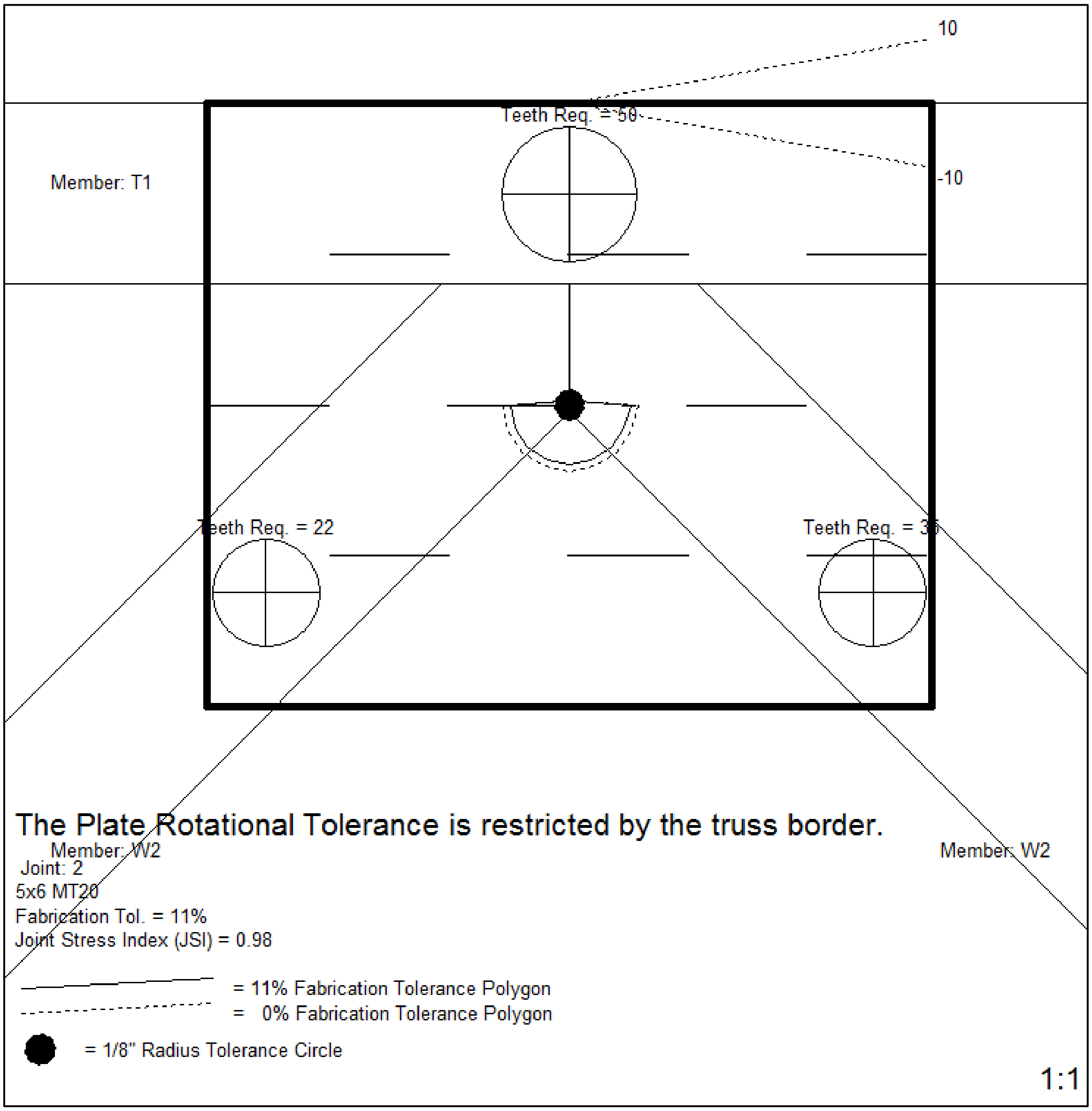
Discussion

The truss shown in this example was a floor truss used in a roof application for an apartment building with a green roof. Because of miscommunication between the truss design staff and the architectural staff regarding the design loads for a green roof nearly every truss used in the roof application was under designed by 14 psf (0.335 kN/m^2). By the time this error had been caught, the trusses had been installed, much of the roofing materials had been applied, and some utilities, including sprinkler piping, had been installed.

It would have been expensive and unnecessary to replace all the trusses in the building. Most lumber members were not stressed to the CSI (Combined Stress Index) limit and could handle the additional load. There were only minor plate size changes at various joints so, it was felt that the trusses could be reinforced where needed. Because of the large number of trusses that required reinforcement, a closer look at optimizing the repair material and installation time was warranted. If there were only a few trusses affected, OSB gussets would have been used with notches cut around each of the sprinkler pipes. The large number of trusses and pipes made applying the OSB gussets impractical.

In addition to providing truss design specifications, the ANSI/TPI-1 standard provides quality control specifications for in-plant truss inspections. The standard process for in-plant quality control is to print out a full-size joint diagram on translucent medium. The joint diagram shows the acceptable placement and rotational tolerances for each individual critical joint and can be placed directly on the actual joint to determine if the plate placement is adequate. On the following page, the joint diagram is shown for joint 2 of the example repair truss with the correct loading applied. Section 3.7.7 of the ANSI/TPI-1 standard provides guidelines for truss plate inspection by doing a count of the teeth in each of the members at a joint. A tooth can be counted as contributing to the connection if there is less than 1/32” (0.8 mm) gap between the plate and the wood member at the tooth, the tooth is more than 1/4” (6.4 mm) from any wood edge, and the tooth is not bent over but goes straight into the wood without defects.

A field inspection was performed utilizing several of these printed joint diagrams. The effective number of teeth were counted on a sample of individual joints from a number of different trusses. The inspection showed the original plates had near perfect placement with almost no lumber defects. In the case of Joint 2 that is shown in the joint diagram on the following page, the original plate size for that joint was 4 x 5 (102 x 127 mm) 20 gauge (0.95 mm) plate. The revised loading determined that 5 x 6 (120 x 152 mm) 20 gauge (0.95 mm) plates were required. The required number of teeth for each member is shown on the joint diagram as follows: the top chord required 50 teeth, the left web required 22 teeth, and the right web required 36 teeth. The inspection determined that the original plate generated nearly 60 effective teeth in the top chord and 34 effective teeth in each of the webs. So, for 2 out of the 3 members, the existing plate had sufficient coverage and the third member was very close to meeting the requirements. This proved to be the case for nearly every undersized plate for all affected trusses. Where the joint was close to meeting the requirements, the plate always had enough teeth in the compression web member and usually within 2 teeth for each tension web member. Therefore, it was determined that the diagonal scab details shown on the example would be the appropriate reinforcement for the tension web connection.



The large majority of trusses required only the tension web reinforcement detail as per Note 5 of the example. Many trusses were only accessible from one side so an alternate 2x6 scab detail was developed. These small scabs were able to be cut in the truss fabrication plant on the high speed saw. Additionally the bottom chord splice plate and the top chord bearing detail at the right end of the example truss required reinforcement. There was also concern about potential deflection on a number of the trusses, so 2 x 6 (38 x 140 mm) strong-backs were added. The repairs were performed efficiently and resulted in only a very minor delay of the construction. The following photographs show the completed repairs for the example truss and several of the adjacent trusses.


Example Truss

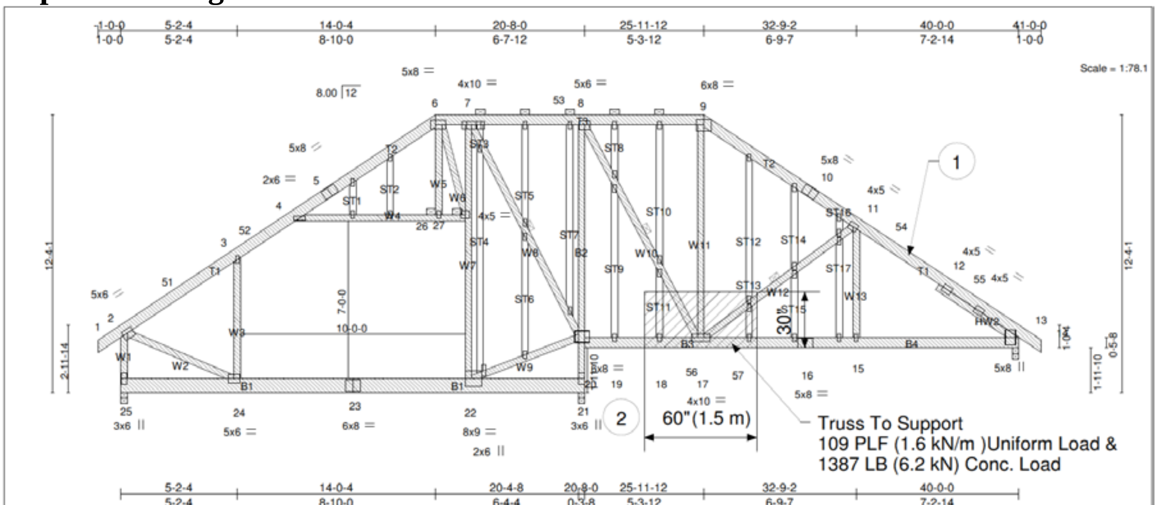

Example Truss

Example 11-3 Attic Truss becomes a Girder Truss

Problem

The framing around an attic structural gable truss changed from the original design requiring extra load applied to the truss.

Repair Drawing



Conditions: Truss to become 2-ply to support load

REPAIR NOTES:
1) Connect adjacent T-905 truss to existing T-905SG truss to make a 2-ply girder.
2-ply truss to be connected together with 10d nails nails as follows:
Top chords connected as follows: 2 X 6 (38 x 140 mm) - 2 rows at 9" (229 mm) oc, 2 X 4 (38 x 89 mm) - 1 row at 9" (229 mm) oc.
Bottom chords connected as follows: 2 X 8 (38 x 184 mm) - 2 rows at 9" (229 mm) oc, 2 X 6 (38 x 140 mm) - 2 rows at 7" (178 mm) oc, 2 X 4 (38 x 89 mm) - 1 row at 9" (229 mm) oc
Webs connected as follows: 2 X 4 (38 x 89 mm) - 1 row at 9" (229 mm) oc
2) Apply 30 x 60" x 7/16" (0.76 m x 1.5 m x 11 mm) OSB gusset (APA rated sheathing 24/16 exposure 1) cut as shown to open side of truss using 10d nails 3" (76 mm) O.C. (1 row for 2x4 (38 x 89 mm), 8 rows for 2x8 (38 x 184 mm)) in all members covered.

Discussion

The original design of this truss placed it directly over a recessed entryway on a bearing wall from joint 20 to joint 17. The load from the porch framing was to transfer directly into this bearing wall. However, the attic structural gable truss was actually set ahead of the recessed wall requiring all of the porch framing to be supported on this truss.

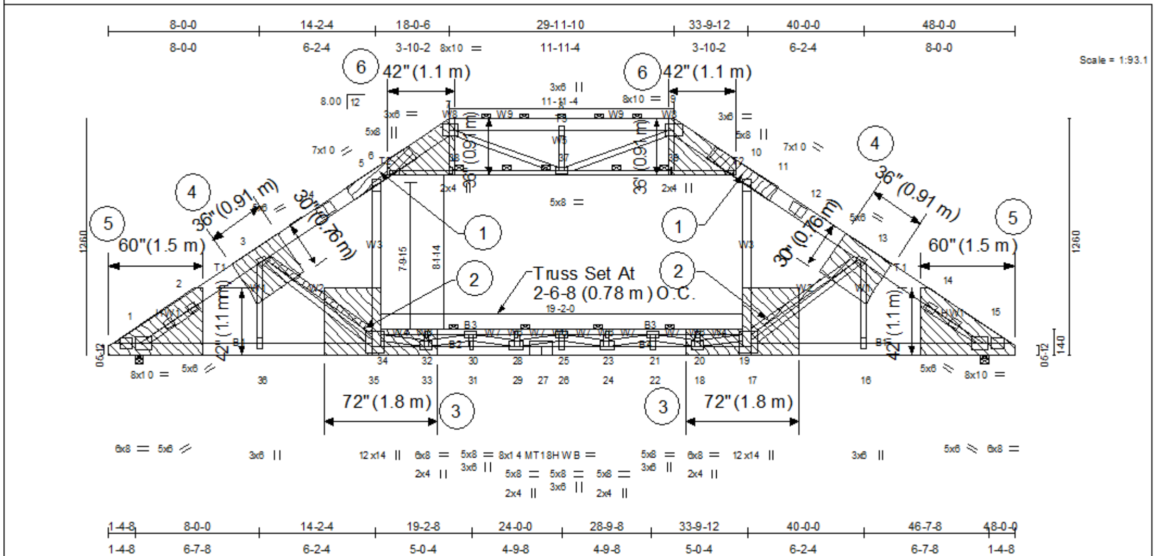
This truss could have been repaired in place without the extra truss, however, the presence of this extra truss made the repair substantially easier. The question as to why there was an extra T-905 truss was never answered completely, but it is believed that the recessed wall moved farther back into the house pulling the porch framing and the T-905SG closer to the next truss allowing them to be joined together. Even after the trusses were joined to form a 2-ply truss, it was still determined that the plate size at joint 17 was inadequate and so the OSB gusset was added to the opposite side of the truss from the porch framing to complete the repair.

Example 11-4 Attic Truss with Increased Spacing

Problem

The attic truss now supports 27% more tributary load than the original design.

Repair Drawing



Conditions: Truss set at 2-6-8 (0.78 m) O.C.

REPAIR NOTES:
1) Install 2 x 10 (38 x 235 mm) SP DSS scab to one side of existing top chord member. Attach scab using 10d nails spaced 3"(76 m) O.C. Scab length = 4' (1.2 m). (2 Locations)
2) Install 2 x 4 (38 x 89 mm) #2 SP or SPF member as new web member. Cut for tight fit with full wood-to-wood contact. (2 Locations)
3) Apply 42" x 72" x 7/16" (1.1 m x 1.8 m x 11 mm) OSB gussets (APA rated sheathing 24/16 exposure 1) cut as shown to both sides of truss using 10d nails 3" (76 mm) O.C. (1 row for 2x4 (38 x89 mm), 2 rows for 2x6 (38 x 140 mm), 3 rows for 2x8 (38 x 184 mm)) in all members covered, driven through and clinched. (2 Locations)
4) Apply 30" x 36" x 7/16" (0.76 m x 0.91 m x 11 mm) OSB gussets (APA rated sheathing 24/16 exposure 1) cut as shown to both sides of truss using 10d nails 3" (76 mm) O.C. (1 row for 2x4 (38 x 89 mm), 4 rows for 2x10 (38 x 235 mm)) in all members covered, driven through and clinched. (2 Locations)
5) Apply 42" x 60" x 7/16" (1.1 m x 1.5 m x 11 mm) OSB gussets (APA rated sheathing 24/16 exposure 1) cut as shown to both sides of truss using 10d nails 3" (76 mm) O.C. (3 rows for 2x8 (38 x 184 mm), 4 rows for 2x10 (38 x 235 mm)) in all members covered, driven through and clinched. (2 Locations)
6) Apply 36" x 42" x 7/16" (0.91 m x 1.1 m x 11 mm) OSB gusset (APA rated sheathing 24/16 exposure 1) cut as shown to one side of truss using 10d nails 3" (76 mm) O.C. (1 row for 2x4 (38 x89 mm), 3 rows for 2x8 (38 x 184 mm), 4 rows for 2x10 (38 x 235 mm)) in all members covered, driven through and clinched where possible.

Discussion

Every truss is designed based on certain loads being applied uniformly over the length of the truss. The live loads are based on climatic or occupancy load and the dead loads are based on the weights of materials for the structure. These loads are all defined on a unit area basis such as lbs/ft^2 (a.k.a psf) or kN/m^2. Trusses are commonly set at every 2' (0.61 m) along the structure. The actual spacing can be calculated by adding together 1/2 the distance to the two adjacent trusses or other structural supports. In this case, the truss was designed to support loads at the common 2' (0.61 m) o.c. spacing, but was actually placed with a spacing of 2'-6 1/2" (0.78 m), a 27% increase. Since the truss is symmetric, the following discussion will be for the left end of the truss but also applies to the right end.

The first repair action was to apply a 2 x 10 (38 x 235 mm) lumber scab along the top chord extending beyond joints 5 & 6. The reason for this step is that the region between those two joints developed a shear stress failure with the extra load. This region of an attic truss is sometimes called the “haunch” and is often a critical region because of the separation of the vertical wall web and the horizontal ceiling chord. In this case the Shear Stress Index (SSI) increased to 1.19. Similar to the CSI limit, the SSI limit is 1.00. So, a value of 1.19 would indicate that this region was now 19% overstressed in shear. It was determined that the lumber scab would be the best way to reinforce this region. The shear stress index is not usually shown on the truss design drawing because it is not required per the ANSI/TPI 1 standard. Therefore, the only ways to determine the shear stress is to analyze the truss in the engineering software or to do a manual calculation.

The remaining issues on this truss were all related to the change in axial forces which are required to be displayed on the truss design drawing. Similar to Example 11-2, where the loading on the truss changes and the truss is undamaged, the full force in each member does not need to be developed, only the change in force. The following table shows some of the critical changes in forces that resulted in repairs at various joints.

			Orignal Force			Revised Forces			Difference	
	Joints		lbs	kN		lbs	kN		lbs	kN
Top Chord	1	2	-5340	-23.75		-6758	-30.06		-1418	-6.31
	5	6	-3917	-17.42		-5133	-22.83		-1216	-5.41
	6	7	-1666	-7.41		-1996	-8.88		-330	-1.47
Bottom Chord	1	36	4215	18.75		5314	23.64		1099	4.89
	32	34	-1265	-5.63		-478	-2.13		787	3.50
Webs	6	38	-2873	-12.78		-3903	-17.36		-1030	-4.58
	33	34	2066	9.19		3035	13.50		969	4.31
	3	35	-481	-2.14		-2579	-11.47		-2098	-9.33
	3	34				3111	13.84		3111	13.84

Instructions 2, 3, & 4 involved adding a new web from joint 3 to joint 34 and also provides a good discussion point on the differences between the software designing individual joints and using OSB gussets to cover multiple joints for a repair. The original force in web 3-35 was only -481 lbs (-2.14 kN), but after adding the web 3-34, the force in web 3-35 increased to -2098 lbs (-9.33 kN) while the force in member 3-34 became 3111 lbs (13.84 kN). This change in force is substantially disproportionate to the actual change in loading. The reason for the new web was to improve triangulation. The increased spacing caused a CSI failure in the room vertical member 5-35, the upper bottom chord member from joint 32 to 34, and the web member 33-34. Adding the web actually lowered the force in the vertical and horizontal members because of the improved triangulation. The new web improved the model but because webs 3-34 and 3-35 are nearly parallel with only a small gap between them, the forces in the two webs increased substantially. If the members had been plated separately, the actual forces would be close to the design forces. When the wood gussets are applied over multiple joints and the two webs are connected at both ends using the same two sets of gussets, the wood gussets create a load smoothing effect and the two webs act as a single unit. This creates a situation where the forces produced by the software may be substantially overstated and it may not be necessary to develop the full change in the forces. If there is doubt as to this load smoothing effect, the repair should be designed to accommodate the full change in force. If, in the judgment of the engineer, the load smoothing effect is in place then a lesser repair can be generated. In this case, it was felt that the OSB gussets in notes 3 & 4 provided sufficient coverage for joints 3, 34, & 35 because of the combination of the following reasons:

- The combination of the nearly parallel webs and wood gussets resolved the CSI failures because the new web prevented bending of the vertical member at joint 34,
- The two nearly parallel webs act as a single unit because of the wood gusset coverage,
- The absolute value difference of the forces in the nearly parallel webs was 1013 lbs (4.51 kN),
- The change in force in web member 33-34 was similar, namely 969 lbs (4.31 kN).

As a result, the gussets in notes 3 & 4 were sized to add approximately1000 lbs of capacity.

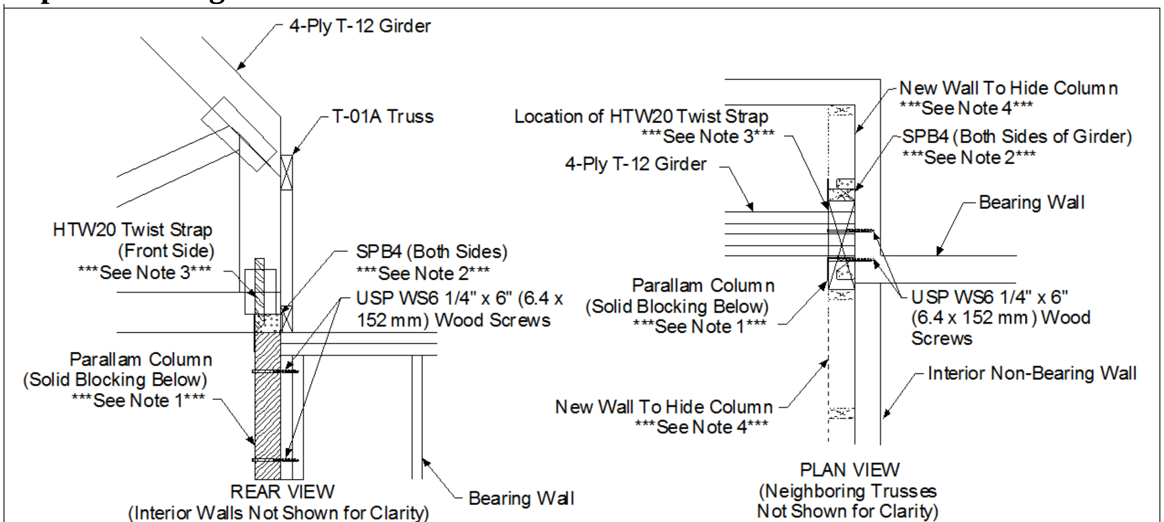
Note 5 identified the need to reinforce the heel joint. The forces in these members changed proportionally to the increase in truss spacing, and so the gussets were sized for the change in force. Note 6 calls for a gusset on only one side because the 2x10 scab from Note 1 was already present on the opposite side. Having the gusset only applied to one side greatly reduces the shear capacity of each nail because the connection is in single shear. In this case, the difference in compressive force was fairly small, and the gusset easily met the required reinforcement even with the single shear nails.

Example 11-5 Girder Truss with No Support at One End

Problem

The girder truss was designed 3 1/2” (89 mm) too short and out into a cantilevered section not designed to support the reaction from the 4-ply truss.

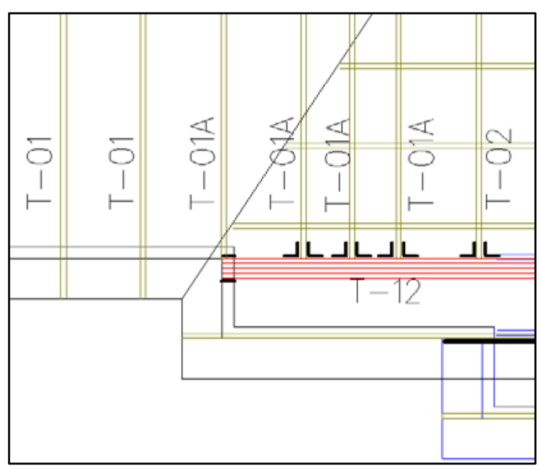
Repair Drawing



REPAIR NOTES:
1) Install 3-1/2" x 11-7/8" (89 x 302 mm) Parallam Column below 4-ply T-12 truss as depicted. Column to be installed with the short face of column 1-1/2" (38 mm) forward of front face of girder. Connect column to existing exterior bearing wall using 2 rows USP WS6 1/4" x 6" (6.4 x 152 mm) or equivalent Wood Screws spaced 12" (0.30 m) O.C. ***NOTE: Solid blocking must be provided below column to foundation.
2) Install (2) USP SPB4 or equivalent Bearing Enhancers, (1) to each face of girder.
3) Install USP HTW20 or equivalent Twist Strap to front face of girder in location depicted. Fill all available nail holes using 10d nails.
4) Construct an additional interior non-bearing wall on each side of column as depicted using standard framing practices.

Discussion

This repair resulted from a combination of design and construction errors and miscommunication. The truss being shifted out into the cantilever could have been avoided if the loads had been tracked down through the structure during the truss design process. The girder being 3 1/2” (89 mm) too short related to conflicting dimensions in the plans. A partial truss placement plan is shown to the right to provide insight into how it was anticipated that the corner would come together, but when it was framed, the bump-out wall was shifted over from where it is drawn and is over the cantilevered floor system as shown in the photograph on the next page.



Several possibilities were considered for this repair including replacing the girder truss with a longer version and stubbing off the whole series of supported trusses, or using a cantilevered beam in the attic with a massive hanger. After some negotiations with the builder, it was determined that the best solution was to add a column designed for the eccentric load and sacrifice a little bit of the room width to build a second wall inside the existing side wall of the bump-out. It was determined that a wide column designed with an offset load would transfer the load back into the wall. The column model for this application is shown to the right. The interior wall and the screws would prevent the column from rotating out into the bump-out. To hide the column and prevent any unsightly steps in the wall, an interior non-bearing wall was framed to continue the wall for the length of the room.

The connection of the girder to column required two separate connectors. The bearing enhancers were installed because the design reaction was greater than the allowable crushing strength of the bottom chord of the truss, but the bearing enhancers did not provide sufficient uplift capacity for girder truss. The twist strap was installed over the bearing enhancers to establish the uplift connection.

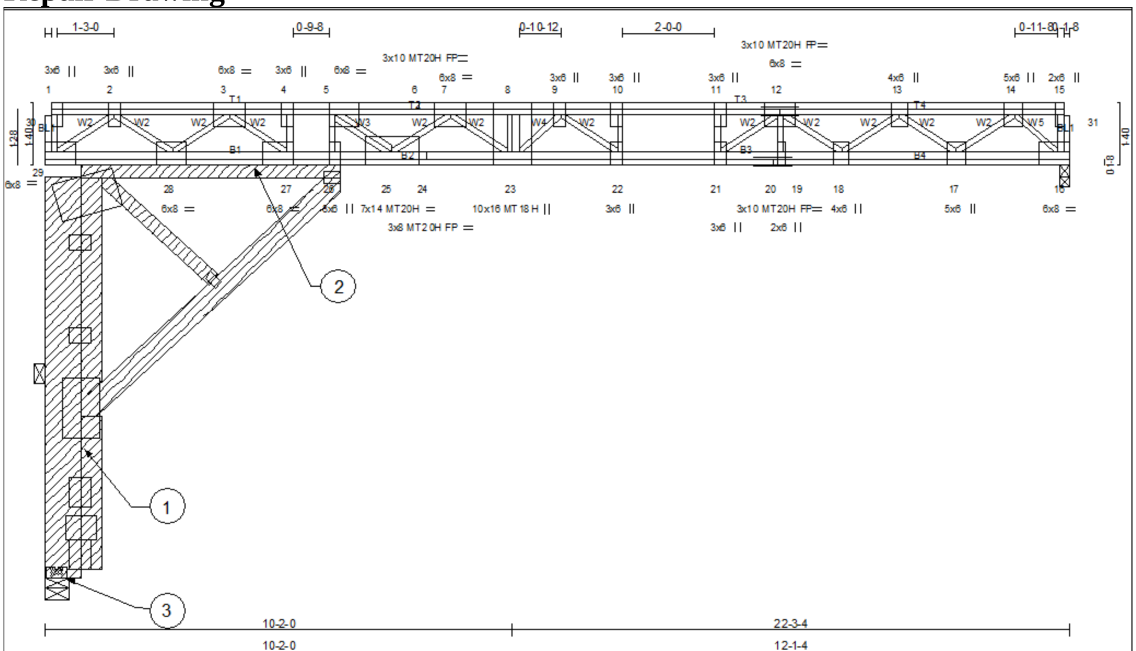
The only item left was to make sure there was solid blocking through the two floors and wall to the foundation wall which was easily accomplished after the post was added. A photograph of the completed repair is shown to the left.

Example 11-6 Invalid Continuous Bearing

Problem

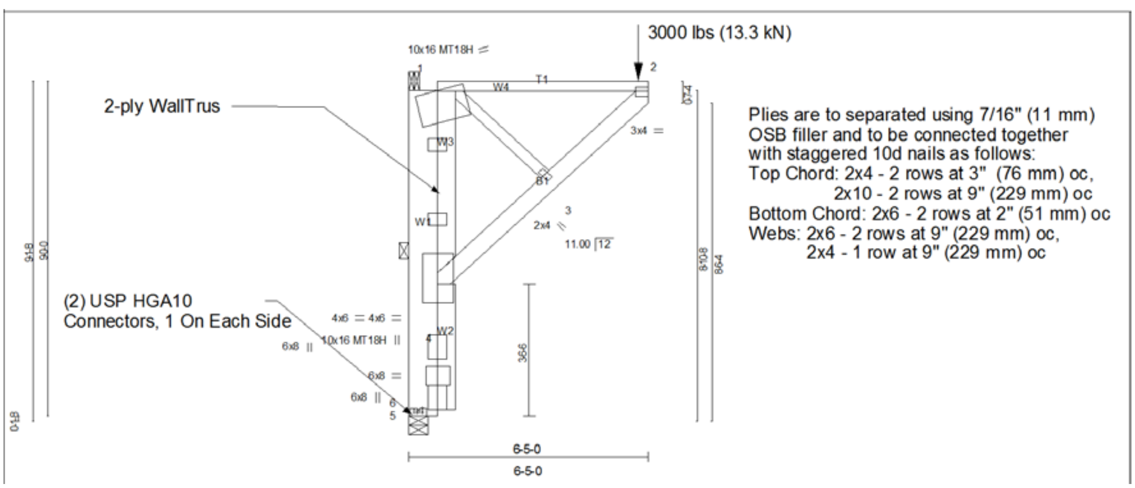
A floor truss was designed with a 6' (1.8 m) long section of continuous bearing at the left end. After installation, it was discovered that the wall that was thought to be bearing was not, effectively increasing the span of truss.

Repair Drawing



Conditions: Wall truss to be created to act as bearing

REPAIR NOTES:
1) Fabricate (1) 2-ply WallTrus for each truss to be repaired. Plies to be connected per Engineering Drawing except that the plies are to be separated by 7/16" (11 mm) OSB filler. See attached sheet 2 of 2 for fabrication details.
2) Connect WallTrus to floor truss using (2) rows USP WS6 1/4" x 6" (6.4 x 152 mm) or equivalent wood screws with 1 row in each ply of the WallTrus. Total screws required = 14. ***Note: Pre-drill through the top chord of the Walltrus using a maximum 5/32" (4.0 mm) diameter bit.
3) WallTrus to be supported using (2) USP HGA10 or equivalent connectors, one on each side.



Discussion

This error was made in the design department when a 6' (1.8 m) long wall was inadvertently assumed to be bearing. This truss was on a lower level of a multi-story building. The framing for the building was complete and the utilities were being run when the problem was noticed. This truss had numerous wires, pipes, and ducts passing through the truss. The CSI's for the truss were already near the limit with the section of continuous bearing. When the truss was run as a simple span, there were several CSI failures and a majority of the plates required reinforcement.

Similar to Example 11-5, the best repair option was actually outside the truss itself. After investigating the locations of the ducts, wires, and pipes that passed through the truss, it was determined that it would be impractical to repair the truss in place or replace it. The only cost effective option was to make the non-bearing wall bearing.

The 2-ply wall truss shown in this example was designed to work in a composite fashion with the existing truss. The wall truss was sized to fit below the truss and between the bottom and top plate of the bearing wall inside the non-bearing wall. Once it was loaded vertically, the truss generated a horizontal reaction of 2,085 lbs (9.27 kN) at the bottom and top of the wall truss. At the top, the horizontal force was resolved back into the original truss using the wood screws. At the bottom, the two angles were chosen to transfer this horizontal force into the bottom plate of the wall and ultimately into the floor diaphragm. The builder then agreed to frame a non-bearing wall underneath the wall truss to complete the wall panel.

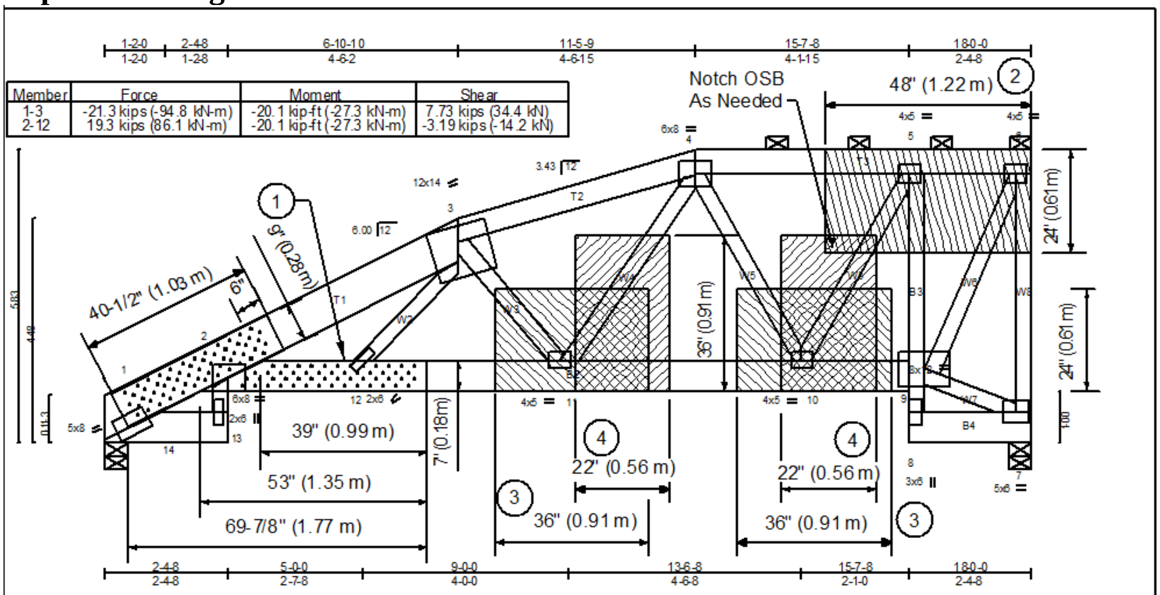
The innovative approach to this repair allowed all the utilities to remain in place saving significant cost and time relative to the utilities being pulled back. Both this example and the previous one were included to show that sometimes, the best repair may occur outside the perimeter of the truss.

Example 11-7 Under Loaded Girder 2

Problem

The required uniform load was only applied to a small portion of the bottom chord instead of the whole length.

Repair Drawing



Conditions: Underloaded Girder

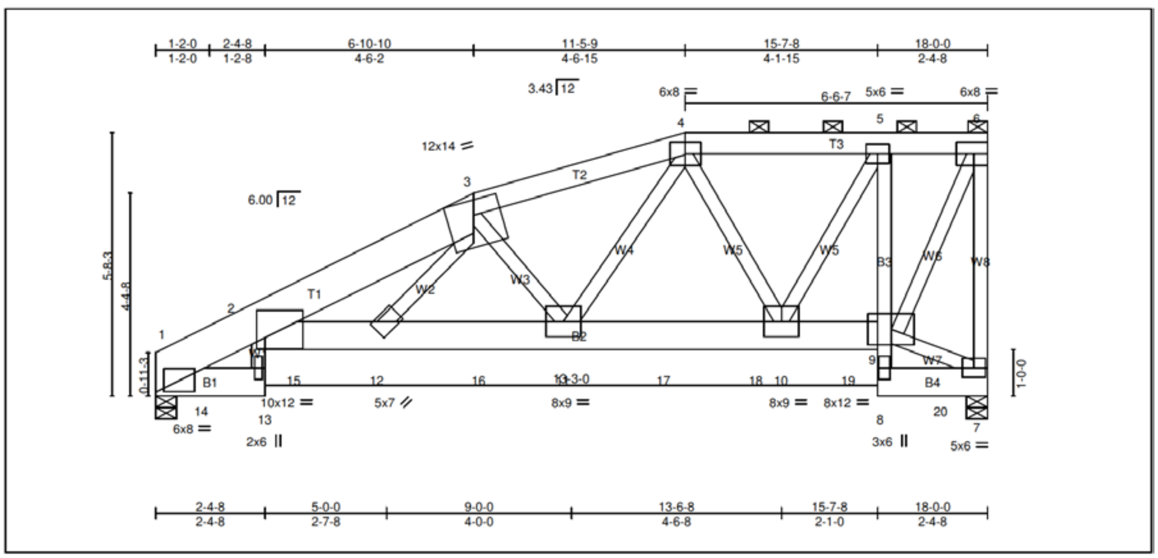
REPAIR NOTES:
1) Install 3 gauge (6.07 mm) Steel Plate w/ 9/32" (7.14 mm) diameter holes as shown to open side of truss. Fill all holes using 1/4" x 6" (6.4 x 152 mm) USP WS6 or equivalent wood screws, 112 screws total. NOTE: Remove any existing bolts in truss in the area where steel plate is to be installed.
2) Apply 24" x 48" x 23/32" (0.61 m x 1.22 m x 18 mm) OSB gussets (APA rated sheathing 48/24 exposure 1) cut as shown to both sides of truss using 1/4" x 6" (6.4 x 152 mm) USP WS6 or equivalent wood screws spaced 6" (152 mm) O.C. (1 row for 2x4 (38 x 89 mm), 2 rows for 2x6 (38 x 140 mm)) in all members covered.
3) Apply 24" x 36" x 23/32" (0.61 m x 0.91 m x 18 mm) OSB gusset (APA rated sheathing 48/24 exposure 1) cut as shown to open side of truss using 1/4" x 6" (6.4 x 152 mm) USP WS6 or equivalent wood screws spaced 6" (152 mm) O.C. (1 row for 2x4 (38 x 89 mm), 2 rows for 2x8 (38 x 184 mm)) in all members covered. Stagger screws from opposite side gusset. (2 Locations)
4) Apply 22" x 36" x 23/32" (0.56 m x 0.91 m x 18 mm) OSB gusset (APA rated sheathing 48/24 exposure 1) cut as shown to supporting side of truss set between supported T-05 trusses using 1/4" x 6" (6.4 x 152 mm) USP WS6 or equivalent wood screws spaced 6" (152 mm) O.C. (1 row for 2x4 (38 x 89 mm), 2 rows for 2x8 (38 x 184 mm)) in all members covered. Stagger screws from opposite side gusset. (2 Locations) NOTE: OSB may be notched as needed to fit around previously installed OSB at step 2.

Discussion

The problem with this truss was discovered when the reviewer noticed that even though the bottom chord appeared to be loaded with approximately 1,000 plf (1.45 kN/m) for its entire length, one reaction was less than 1,000 lbs (4.45 kN). To complicate the issue, this girder truss had been supplied for several houses for a large production builder prior to the mistake being caught. Each of these houses was in a different stage of construction, but fortunately none were completely finished at the time this issue was discovered. At some point in the design process, the software applied the load only from the left bearing to joint 13 even though it showed application for the entire length of the truss.

For most wood trusses, the predominant forces are axial. In fact the ANSI/TPI-1 standard requires only the axial tension and compression forces to be provided on the truss design drawing. It does not require reporting of the moment and shear forces, but the moment and shear forces are available to users of the software. The moment and shear forces become much more important whenever the bottom chord members come to a point and are plated at the same joint as the top chord members. In this case, the connection at joint 2 is critical due to the geometry of the truss. The truss effectively becomes top chord bearing where the member between joints 1 and 3 behaves more like a cantilevered beam than a truss member and so the moment and the shear forces are provided.

Various options were considered for this repair. One solution could have been to replace the girder in each house. However, replacing each of the girders would have been very costly in both time and money. Using OSB gussets and scab trusses were also considered, but this girder was supporting other trusses for its full length and no combination of OSB gussets and scab trusses could be installed on only one side or between the supported trusses that transferred enough force through the connection at joint 2. The steel side plate surfaced as the most effective repair.



The revised truss design is shown above. The plate size at joint 2 increased from 6x8 (152 x 203 mm) to10x12 (254 x 305 mm) which was shared over the 8 faces of the 4-plies, and the repair was only going to be able to be applied to one face. In addition, the lumber for the top chord member was inadequate for the moment and shear that were being transferred with the correct loads and needed to be reinforced. The steel plate was sized to meet the geometric constraints of the members of the truss, transfer the required force between the top and bottom chord, and reinforce the top chord lumber between joints 1 and 2 while not exceeding the allowable tip load of the screws. The tip load rather than the normal shear capacity of the screws was the limiting factor because the steel plate was to be placed on the opposite side of the truss from the loaded face.

The method used to calculate the load on each screw was the same as for an eccentrically loaded bolt or screw group. The process involved calculation of the polar moment of inertia of the bolt or screw group, the horizontal and vertical force components on each connector, and the resultant force. The equations are as follows:

$$I_O = I_x + I_y = \sum x_i^2 + \sum y_i^2$$

$$V_i = Shear + Moment \times \frac{x_i}{I_O} \quad and \;\; H_i = Axial\ Force + Moment \times \frac{y_i}{I_O}$$

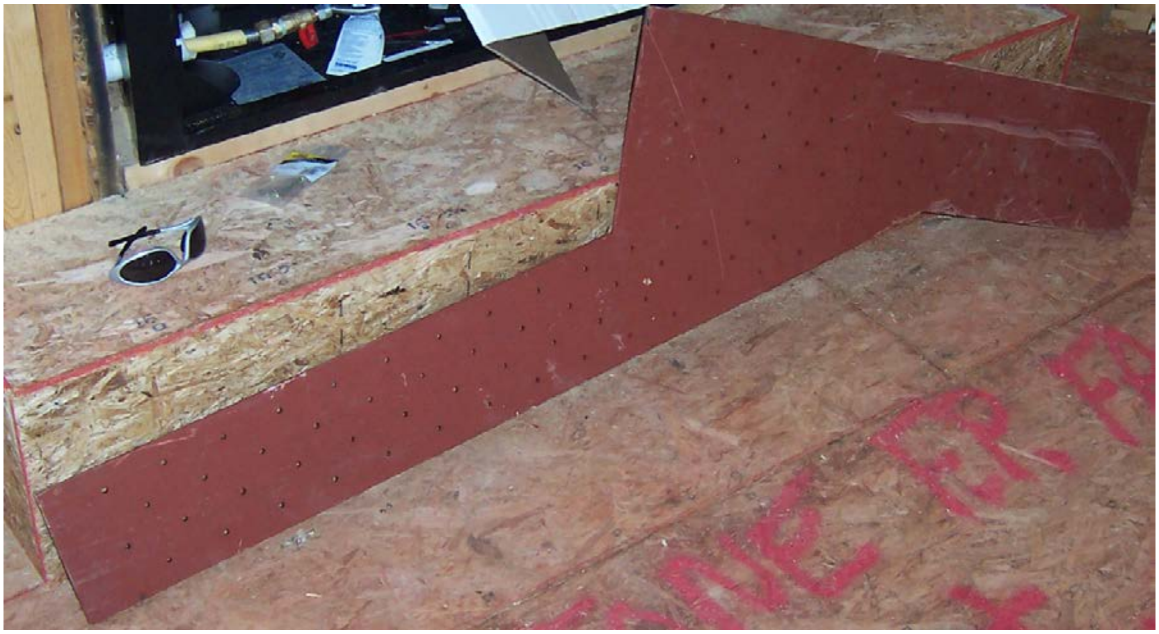
$$R_i = \sqrt{(V_i^2 + H_i^2)}$$

Where

- x_i & y_i are the respective distances to the centroid of the connector group for screw i
- V_i & H_i are the vertical and horizontal forces on screw i
- R_i is the resultant force on screw i

The above process can be used to calculate a moment connection when required for a truss repair. However, as noted earlier, the moment and shear values are not required to be on the truss design drawing and therefore may not be readily available to those who do not have access to truss design software. It may be important to find a way to model the truss to determine the moment and shear values when there is little or no triangulation at a particular point. Fortunately, the use of axial forces are sufficient for the vast majority of repairs.

Several of the other joints had plates that were undersized as well. Each of these joints were able to be reinforced with OSB gussets cut to fit between the supported the trusses or on the opposite side of the truss fastened with the screws. The steel plate repair cost the customer about a week in the schedule for the design and manufacture of the steel plate, but it was felt that this solution was in the end better than replacing the girders due to less disruption in the overall construction process. The following photos show the steel plate prior to and after installation of the 4-ply girder.

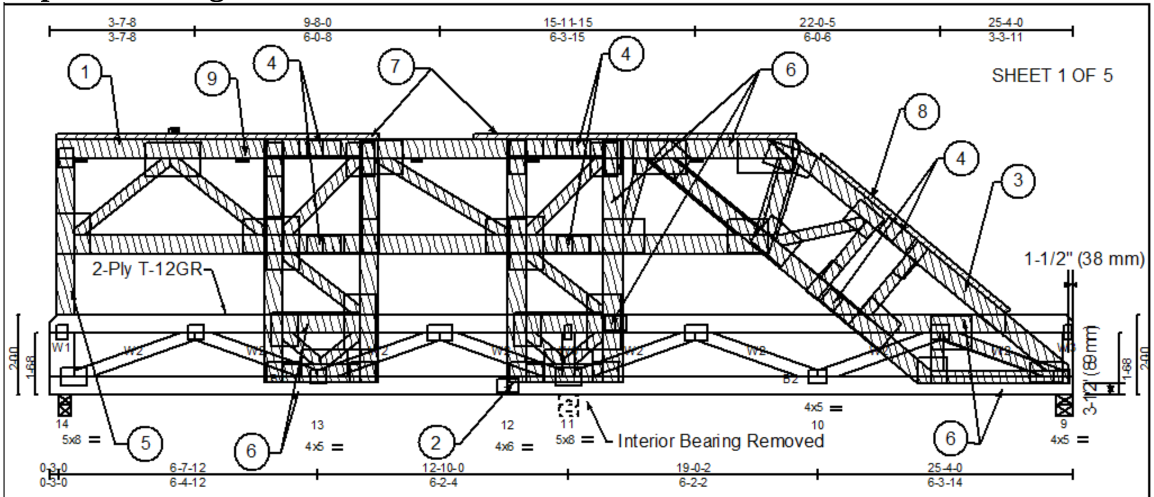


Example 11-8 Removal of an Interior Bearing

Problem

The shallow girder truss was designed with a post near the center which was not installed.

Repair Drawing



Conditions: Interior bearing removed

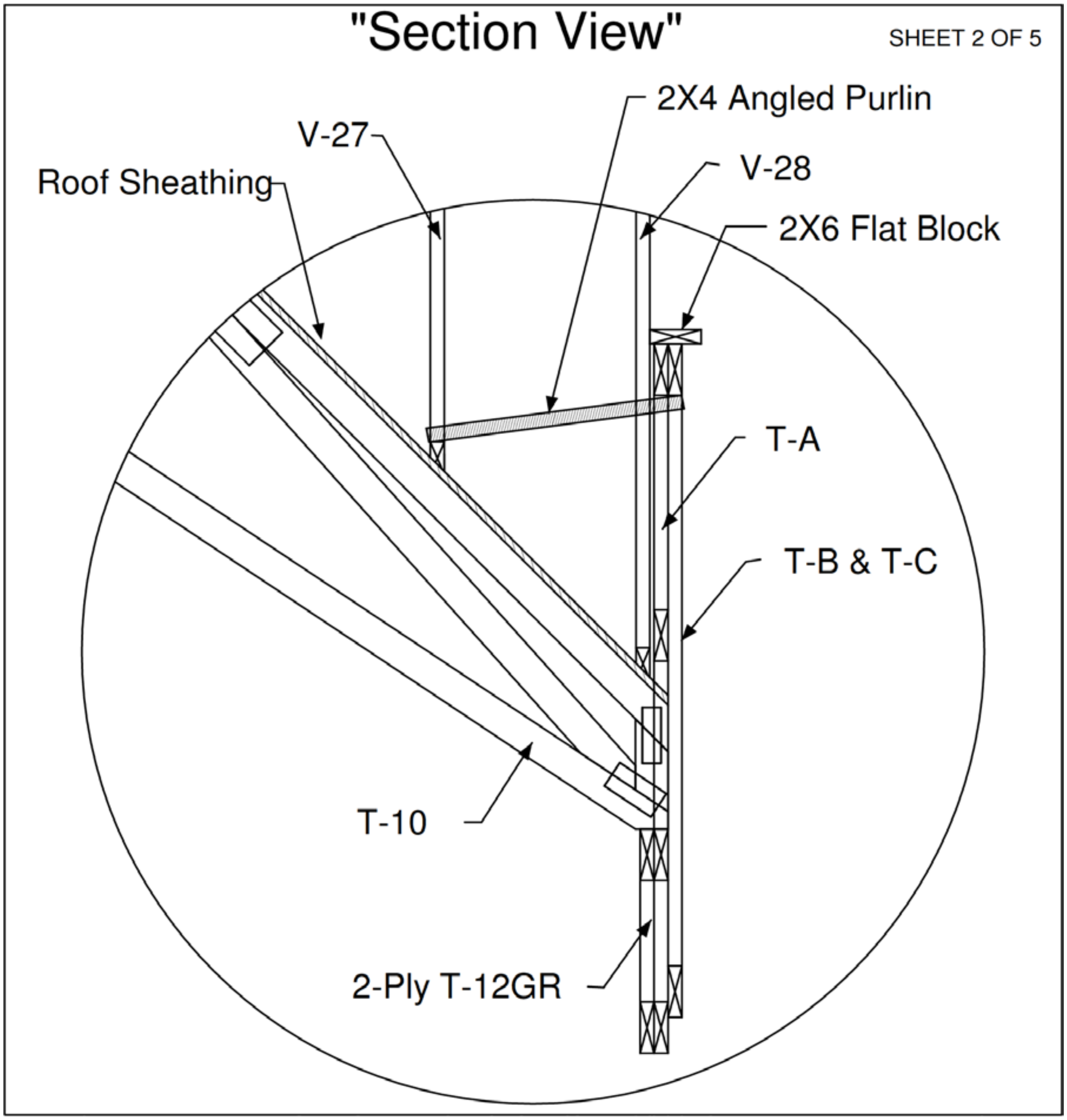
REPAIR NOTES:

1) Fabricate (1) T-A Spider truss (3 sections) for each truss to be repaired. See attached sheet 3 of 5 for fabrication details.
2) Fabricate (2) T-B Scab trusses for each truss to be repaired. See attached sheet 4 of 5 for fabrication details.
3) Fabricate (1) T-C Spider truss (2 halves) for each truss to be repaired. See attached sheet 5 of 5 for fabrication details.
4) Using a hydraulic press, install 5x10 (127 x 254 mm) MT20H side plates to both faces of T-A and T-C spider truss top and bottom chord members at field-splice locations. (6 Locations)
5) Install (1) T-A Spider truss above existing T-12GR truss as shown.
6) Install (2) T-B and (1) T-C trusses to face of existing T-12GR and T-A spider truss as shown and attach using the following pattern:
-Attach T-B and T-C trusses to existing T-12GR truss using 2 rows 1/4" x 4-1/2" (6.35 x 114 mm) USP WS45 or equivalent wood screws spaced 4" (102 mm) O.C into the top chord member and 1 row into the bottom chord member of T-12GR.
-Attach T-B to T-A truss using 2 rows 10d nails spaced 4" (102 mm) O.C. in all aligning members.
-Attach T-C to T-A truss using 2 rows 1/4" x 3" (6.35 x 76 mm) USP WS3 or equivalent wood screws spaced 4" (102 mm) O.C in all aligning members.
7) Install 2 x 6 x 8' (38 mm x 140 mm x 2.4 m) long member above top chord of T-A spider truss to form an L-brace as shown. Connect bracing to spider truss top chord using 10d nails spaced 8" (203 mm) O.C. (2 Locations)
8) Install 2 x 6 x 6' (38 mm x 140 mm x 1.8 m) long member above top chord of T-C spider truss to form an L-brace as shown. Connect bracing to spider truss top chord using 10d nails spaced 8" (203 mm) O.C.
9) Install angled 2 x 4 (38 x 89 mm) purlins at 4'-0" O.C. running from bottom edge of T-A top chord members to top edge of adjacent V-27 truss bottom chord member. Attach using (2) 10d at each connection point.

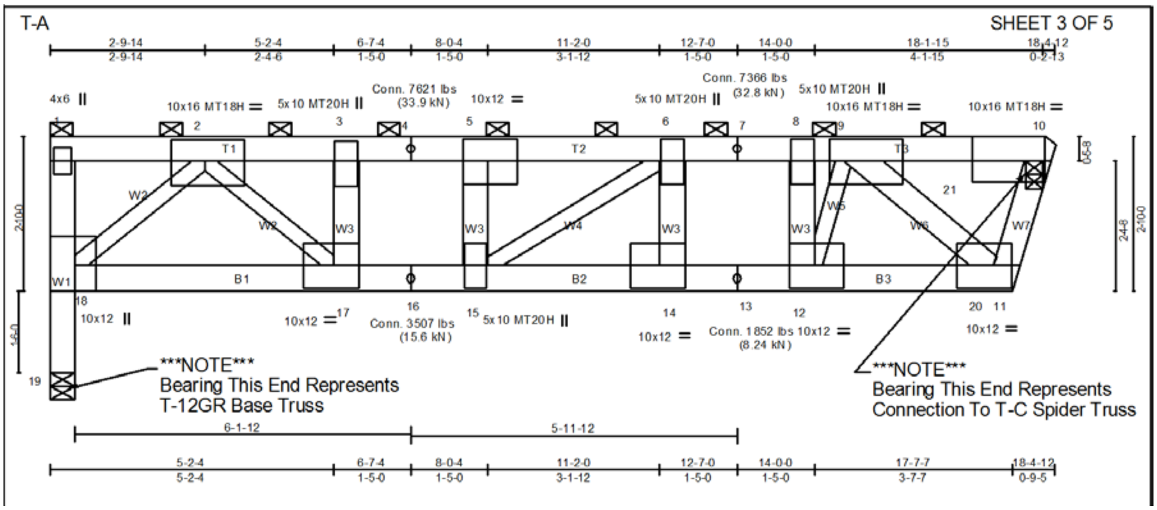
***Refer to attached SHEET 2 of 5 for section view of required repair.

Discussion

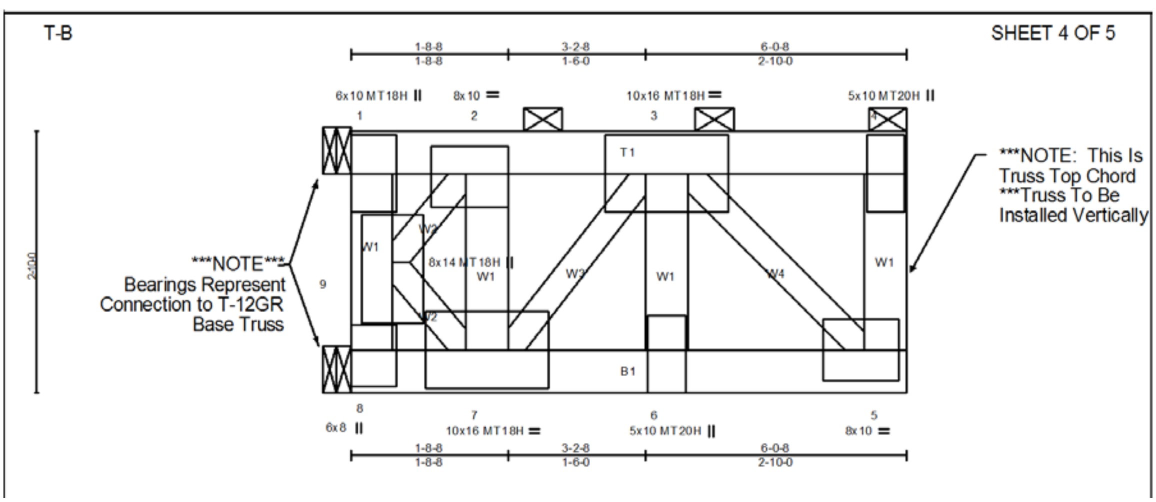
This repair was a very unusual situation for a number of reasons. This girder truss known as T-12GR defined a 2' (0.61 m) step up in the ceiling between the kitchen and family room. (A section view is provided on the next page.) The builder had specifically requested the T-10 truss to bear on top of the T-12GR because they did not want a hanger connection. This request limited the height of the girder truss to 2' (0.61 m) even though there was substantial height above the truss and below the roof for its entire length. On a previous house, the truss manufacturer communicated to the builder that a post was required near the center of the truss which was incorporated into a partial wall between the kitchen and family room. In subsequent houses the builder eliminated the partial wall and post, but the T-12GR truss was designed and built with the expectation that a post was to be added. Several months after the houses were completed, a representative of the builder was doing a review of the homes recently built and found the error.

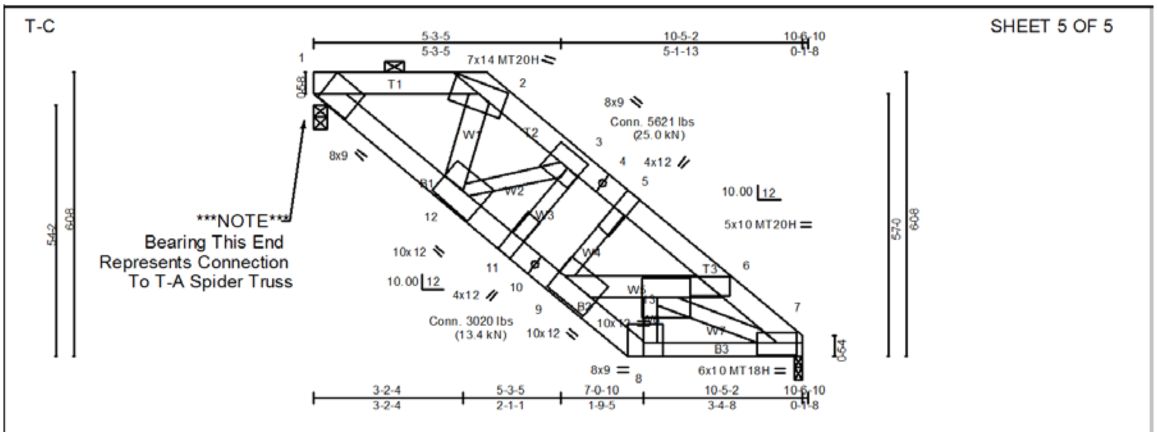


With the bearing removed, the design of the truss had substantial CSI and deflection failures. Other hindrances included the fact that gypsum board was attached to one face for its entire length. On the other face there was an attic room extending ~5' (~1.5 m) from the left end which limited the placement of the leftmost vertical T-B truss. There was a T-10 truss every 2' on top of the truss. Access to the truss was extremely limited due to these hindrances. Fortunately, there had not been a substantial snow storm since the completion of the house, so the girder had only supported the dead load and the truss exhibited no deflection.



The special situation of this girder truss repair required a unique solution. Although access to the truss was severely limited, the substantial space above the T-10 trusses was utilized in the solution. The T-12GR girder was not supporting a lot of load from the T-10 trusses and the long shallow design was the limiting factor in terms of large design deflection. The goal for the repair was to create a composite truss with an increased moment of inertia sufficient to carry the design load without opening either the roof or ceiling. There was access to the attic space but that too was limited and it was determined that no piece of the repair could be longer than about 6' (1.83 m) to get into the attic. The repair was designed to be brought into the attic in seven trusses pieces: a 3 piece spider truss called T-A (shown above), two truss pieces called T-B (shown below), and a 2 piece sloping spider truss called T-C (shown on the next page). The T-A truss provided the increased moment of inertia and the remaining truss pieces were used to connect the T-12GR to the T-A truss. The T-B truss was designed in a horizontal orientation because of a software limitation in dealing with the application of horizontal loads to vertical members, but it was rotated 90º for installation.



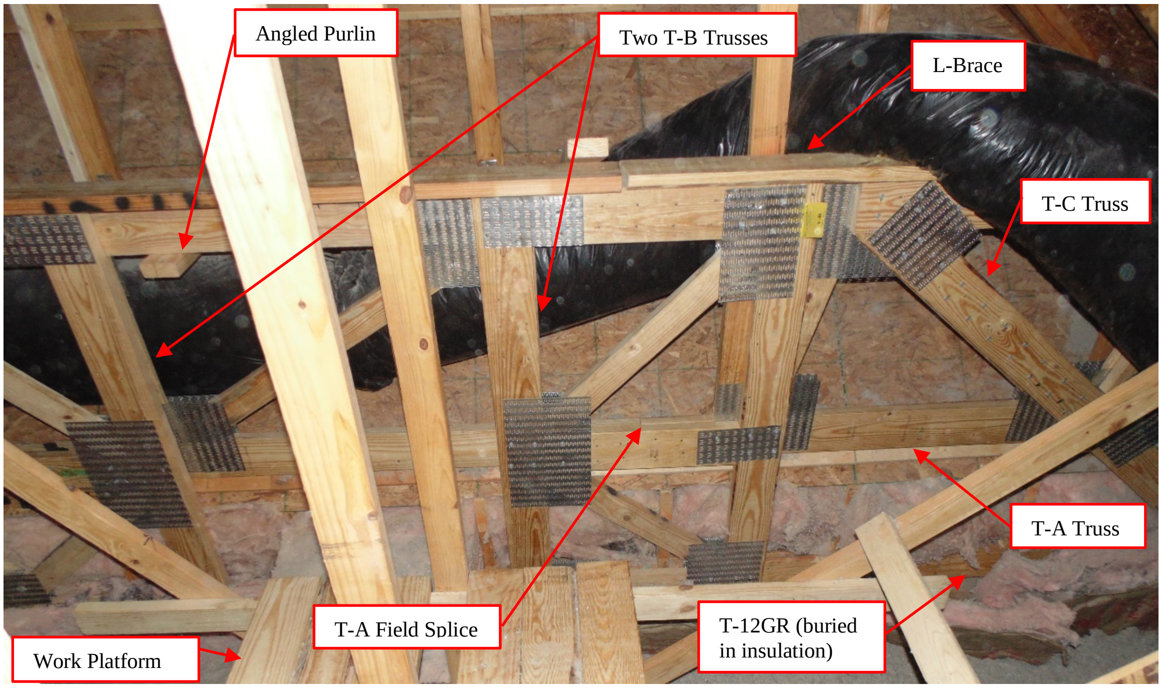


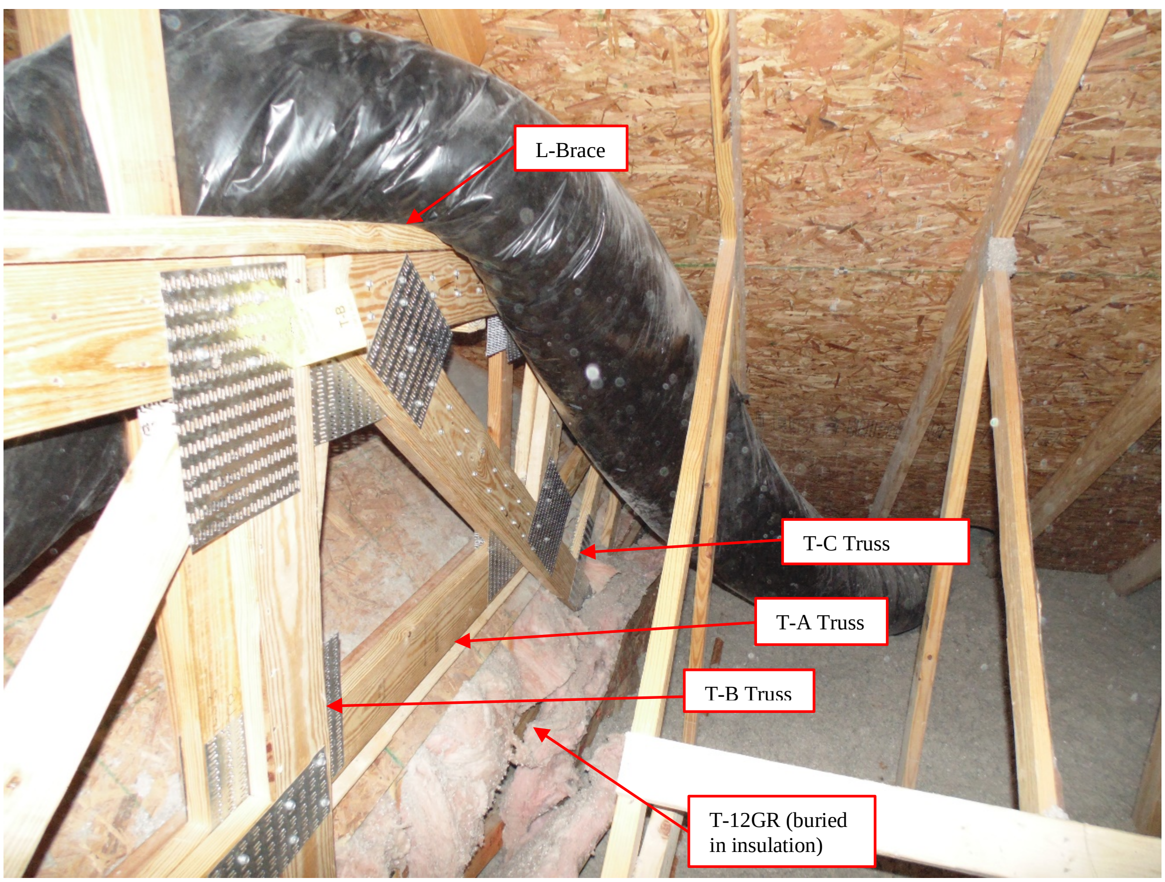
Once the pieces were brought into the attic space and placed near their final location, the spider trusses were spliced using truss plates and a hydraulic field press. There was a gap between the top of the T-12GR and T-A trusses to allow for the heel of the T-10 trusses. At the left end of the repair where there was no access to either face, the end vertical of the T-A truss extended down to bear directly on top of the T-12GR truss. This member was completely in compression, so two toe-nails were used to hold it in place. Looking at the section view, the single ply T-A truss was installed directly above the right ply of the T-12GR truss. The T-B and T-C trusses were then applied to the face of the two trusses. The connections to the 2-ply T-12GR truss required 4 ½” (114 mm) long screws because the composite truss was now 3 plies whereas at the top, the connectors needed to be only 3” (76 mm) long because the assembly was only 2 plies thick. It was determined that nails were sufficient for connecting the T-B and T-A trusses. However, the T-C truss to T-A truss connection required screws. That connection had to be designed using the moment connection method that was discussed in Example 11-7 using the triangular shaped overlap area to transfer the required moment across the connection.

The final critical steps of the repair involved bracing of the top chord of the composite truss. The bracing of the top edge of the T-12GR truss was supplied by the T-10 trusses. The 2x6 (38 x 140 mm) L-brace and the angled purlins were added to properly secure the compression member of the composite truss.

Overall the repair went well. There were some wires and ductwork in the way, but those were relocated with little disruption. Building a work platform in the adjacent trusses above the insulation was a very beneficial step in completing the repair. The repair was completed in one day for each house without opening either the roof or ceiling, with only minimal disruption to the homeowners, and at a greatly reduced cost to alternate repair options.

Very complex repairs of this nature should only be completed by competent individuals with years of experience in repair design, but this example is presented as part of this course to show that sometimes, the most effective repairs may be creative and unique. Photographs of the completed repair are shown on the following page.


Angled Purlin
Two T-B Trusses
L-Brace
T-C Truss
T-A Truss
T-A Field Splice
Work Platform
T-12GR (buried in insulation)

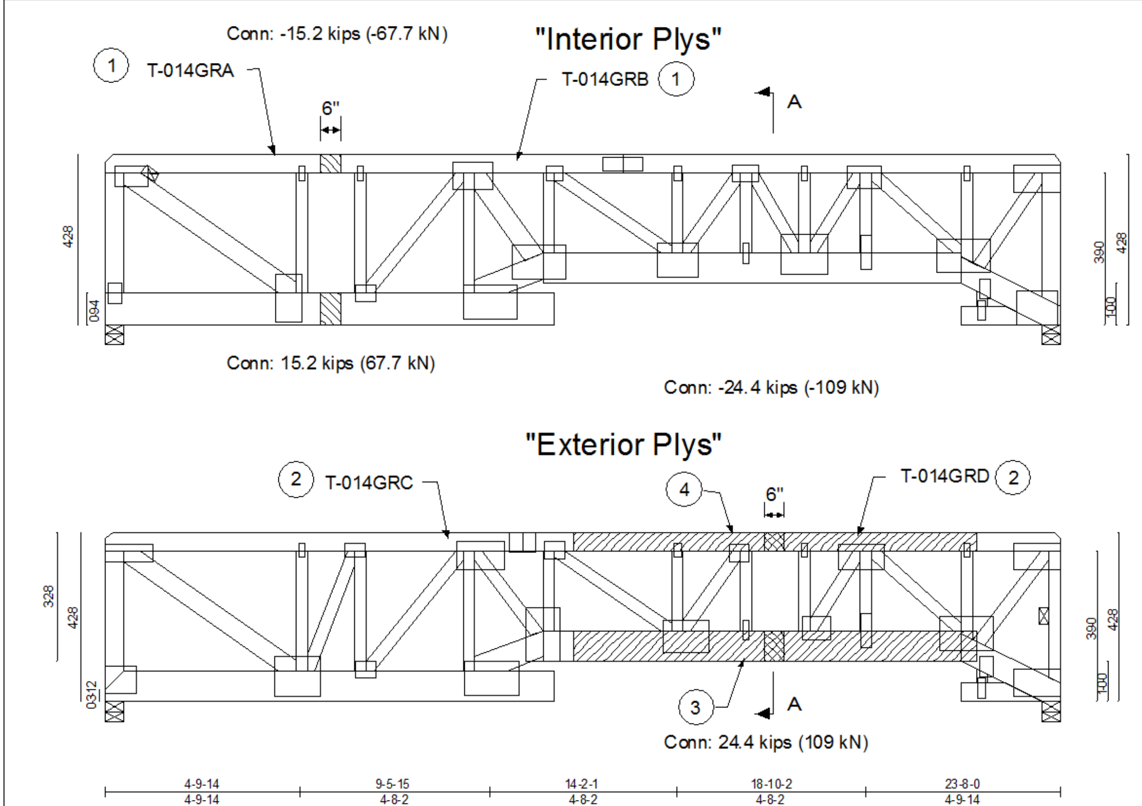

L-Brace
T-C Truss
T-A Truss
T-B Truss
T-12GR (buried in insulation)

Example 11-9 Add a Volume Ceiling to a 4-Ply Girder

Problem

A box ceiling was missed in a 4-ply girder that supported trusses on both sides.

Repair Drawing

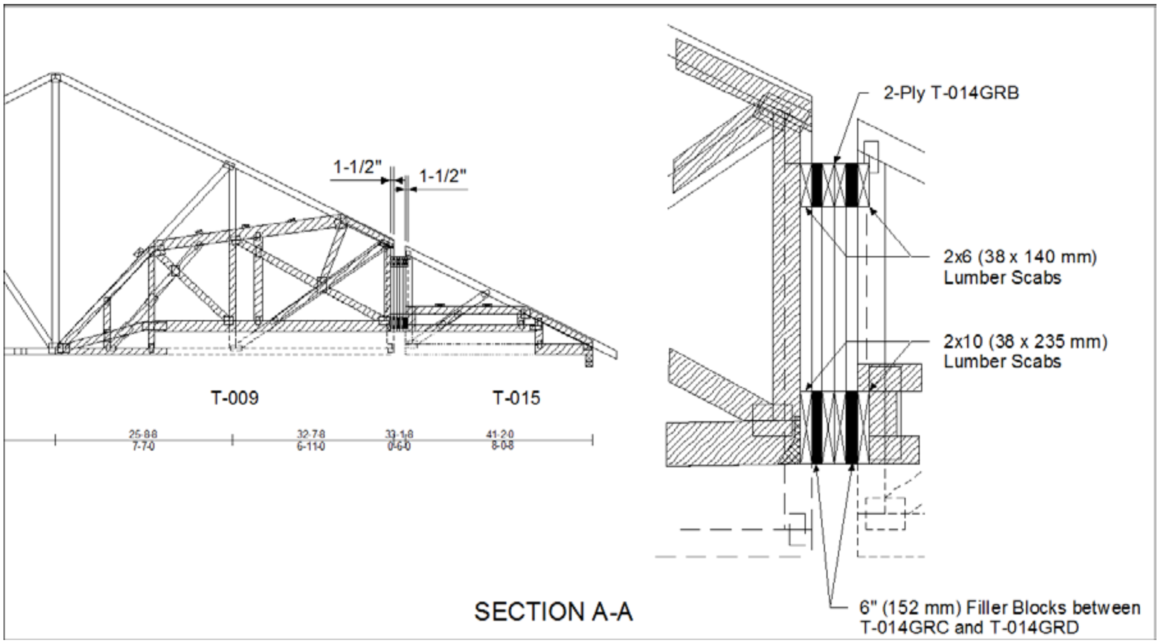


Conditions: Design for replacement of T-014GR

REPAIR NOTES:
1) Install 2-Ply T-014GRA and 2-Ply T-014GRB as interior plys 6" (152 mm) apart. Provide solid block at field-splice location.
2) Install 2-Ply T-014GRC and 2-Ply T-014GRD as exterior plys 6" (152 mm) apart, 1-Ply on each face of previously installed T-014GRA and T-014GRB trusses in step 5. Provide solid block at field-splice location.
3) Install 2 x 10 (38 x 235 mm) DSS SP scab to both exterior faces of T-014GRC & T-014GRD spider truss bottom chord members at field-splice location. Attach scab using 3 rows 1/4" x 6" USP WS6 or equivalent wood screws spaced 4" (102 mm) O.C. Stagger screws from opposite side scab. Scab length = 10' (3.05 m).
4) Install 2 x 6 (38 x 140 mm) DSS SP scab to both exterior faces of T-014GRC & T-014GRD spider truss top chord members at field-splice location. Attach scab using 2 rows 1/4" x 6" USP WS6 or equivalent wood screws spaced 4" (102 mm) O.C. Stagger screws from opposite side scab. Scab length = 10' (3.05 m).
5) ***4-ply truss to be connected together with 1/4" x 6" USP WS6 or equivalent wood screws as follows:
Remaining top chords not covered by previously installed scab in step 8 connected as follows: 2x6 (38 x 140 mm) - 2 rows at 4" (102 mm) O.C. Remaining bottom chords not covered by previously installed scab in step 7 connected as follows: 2x10 (38 x 235 mm) - 3 rows at 4" (102 mm) O.C. Webs connected as follows: 2x4 (38 x 89 mm) - 1 row at 9" (229 mm) O.C., 2x6 (38 x 140 mm) - 2 rows at 9" (229 mm) O.C., 2x8 (38 x 184 mm) - 3 rows at 9" (229 mm) O.C., 2x10 (38 x 235 mm) - 3 rows at 9" (229 mm) O.C. ***NOTE: All screws to be installed from the T-009 face of truss.

Discussion

This situation is similar to the volume ceiling repairs presented in Chapter 10 where a box ceiling crosses over a 4-ply girder. There are a few notable differences in this situation. The first is that this girder supports trusses on both faces instead of one face. The repair for this example was done in two adjacent 4-story town-house units instead of a single 2-story stand-alone residence with window access. The section view below shows the scab trusses that were designed for the T-009 and the T-015 trusses that were supported by the girder truss. (The scab truss shown on the T-009 was designed to match multiple trusses, so the webbing is a little unusual.) Chapter 10 provides a sufficient discussion of how to design scab trusses, and so this example will focus on the replacement of the 4-ply girder.



The main concept of this repair was that two inside plies were different than the two outside plies and both sets were designed as 2-ply spider trusses. The inside plies had their field splice near the left end while the field splice for the outside plies was closer to the right end. In this way the outside plies provided the required reinforcement for the inside plies at the left field splice, and the inside plies provided substantial reinforcement for the outside plies field splice. The field splice for the outside plies had substantially higher forces due to the shorter height in the volume ceiling and therefore required lumber scabs in addition to the inside plies to complete the reinforcement. With the lumber scabs, the combined section was six plies wide as shown in the section view. Six plies are allowed for girder trusses that support load on both faces per ANSI/TPI 1-2014 Section 7.5.2.4. However, if the truss supports load only one face, the maximum number of plies is five. It is debatable whether the lumber scabs count as additional plies, but the total number of plies is a consideration when doing any repair to a multi-ply girder. It should be noted that the scab trusses of the supported trusses were designed to either hang from or bear on top of the lumber scabs.

The structural concept for this repair design was sound, however the implementation ended up being much more complicated than anticipated. In retrospect, it would have been better to open the roof, remove the existing 4-ply girder and mono trusses, apply the scab trusses to T-009, and replace the 4-ply girder and mono trusses because of the cost of this repair and the delay in the construction schedule was more than expected. So, while there were challenges in the completion of this repair, it provides some good discussion points. Here are some of the lessons that could be learned from this repair:

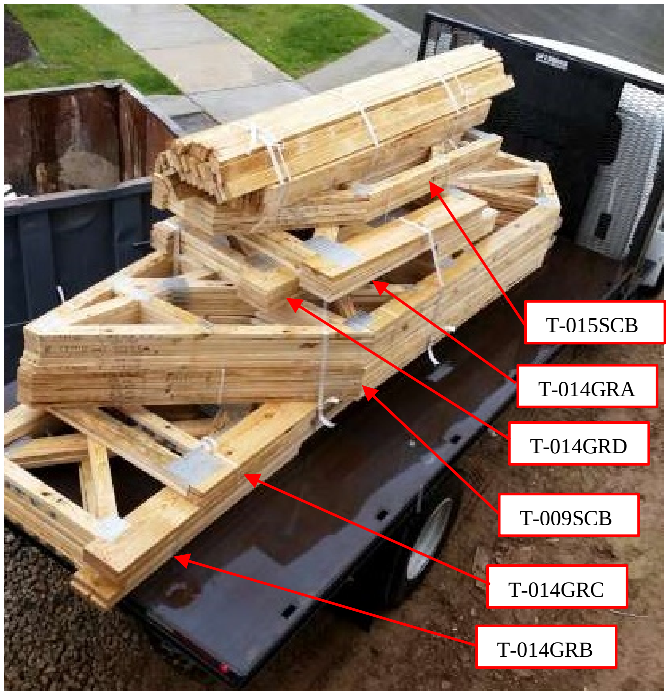
- The structural screws used for this repair or similar ones are a very valuable tool for truss repairs because they have substantial strength, they are self-tapping (meaning they do not necessarily need holes pre-drilled before installing the screws), and they are provided in lengths ideal for many truss repairs. However, they can be expensive. On smaller scale repairs, their ease of installation can make up for their cost. However, in this case, there were over 1200 screws total used in the two repairs which took over 48 man-hours to install them and burned up a couple of drills in the process. The cost of the screws and their installation was more than hiring a crane and a framing crew to do the replacement.

  Also, while the screws went into clean wood smoothly, it was noticed that when the screws were installed where there were truss plates, the screws would often shear off as the screw was penetrating the plates between the second and third ply. Because of this shearing problem, the spacing of the screws was adjusted around the truss plates. Holes could have been predrilled through the truss plates to keep the spacing constant, but the large number of screws to be installed prevented this option. When doing a repair with a large number of screws, it would be good to either plan for the spacing of the screws around truss plates or specify the holes to be predrilled through the plates for joining 3 or more plies together.

- The initial concept for this tray ceiling addition was to repair only the trusses in the area of the volume ceiling. The original idea was that the trusses outside the tray would have their hangers removed but would otherwise remain untouched while the girder truss was cut out and replaced by sliding the spider pieces into place between the trusses on either side. However, this proved to be ineffective because even fully embedded truss plates add thickness to the truss and snag items as they pass by. In this case, the last ply could not be inserted because the truss plates on that ply could not be slid past the truss plates of the adjacent ply. Due to the location of a wall it was decided to cut out the end of all of the trusses in the T-009 series not just the ones getting the tray ceiling. After the spider truss pieces were inserted into place. The ends of the T-009 were reconnected using lumber scabs and OSB gussets. These additional repairs are displayed in the photographs that follow.

- Before doing a complicated repair, consideration should be given to the logistics involved and as much as possible the experience of the crew. In the case of this repair, getting the scab pieces to the fourth floor proved to be a greater challenge than anticipated. Also, the repair crew was not experienced in this type of repair nor were enough workers supplied to get the repair completed in a timely basis. The result was the repair caused a substantial delay in the project. The primary responsibility for a repair engineer is to make the trusses structurally sound. However, the schedule and budget need to be part of the plan in order to make a truly effective repair design.

The repair was eventually completed successfully. The following photographs were taken during the implementation of the repair or after it was completed.



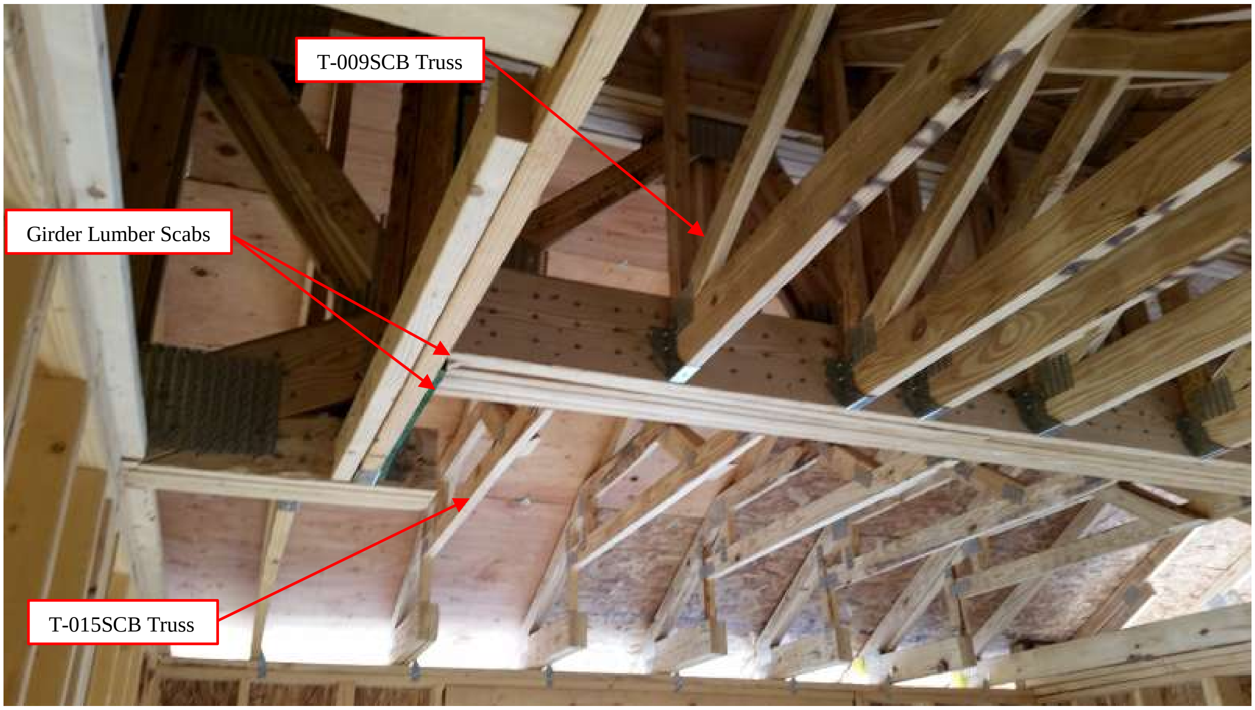
1st Ply of T-014GRC

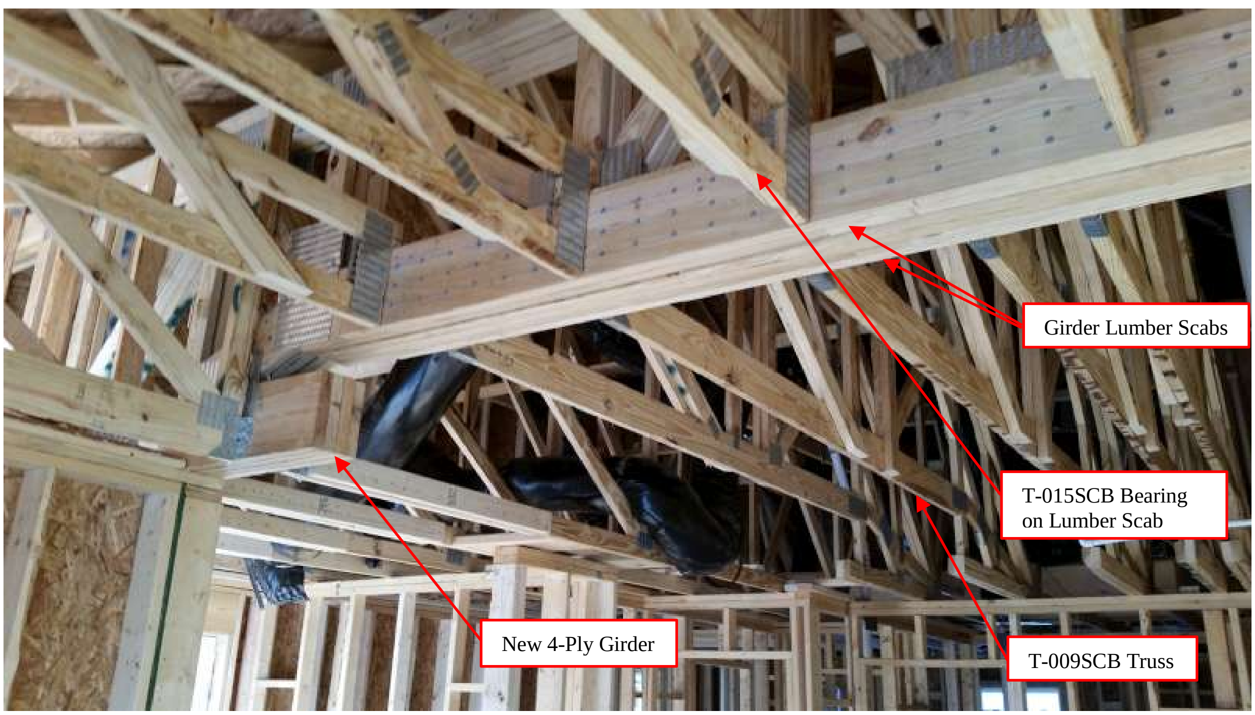
Cut Back T-009 Trusses


New Girder Truss
T-015 Mono Truss


New Girder Truss
Screw Pattern Adjusted around Truss Plates


Repaired T-009 Trusses outside the Tray Ceiling


T-009SCB Truss
Girder Lumber Scabs
T-015SCB Truss


Girder Lumber Scabs
T-015SCB Bearing on Lumber Scab
New 4-Ply Girder
T-009SCB Truss

Conclusion

The purpose of this course series has been to examine various techniques and approaches to repairing, reinforcing, or modifying metal plated wood trusses. While most repairs are fairly straight forward and can use standard repair methods such as lumber scabs and OSB gussets, a small portion of the repairs and modifications are more complex. This course series provides a broad spectrum of the possible situations and suggested solutions for truss alterations.

The first part in the three part series focused on repair concepts and relatively simple repairs. The discussion began with some definitions, followed by truss repair concepts, connections, and some examples of member damage and defects. It concluded with some plate damage examples. Part two of this course series discussed moderately complex repairs. The discussion began with a presentation of manufacturing errors, followed by stubs and extensions, minor modifications which involved adding new members to the truss and ending with major modifications which comprised those repairs that involved removing some portion of the original truss.

This document is the third part of the course series and focused on more complex repairs such as volume ceiling changes and girder modifications. Chapter 10 presented a number of tray ceiling repairs in a single residence. Chapter 11 walked through several repairs involving changes to girder trusses or the loading on individual trusses. The first two parts of this course series handled common repairs, and so a repair designer is likely to face some very similar truss repairs as those discussed even into the tray ceiling repairs of Chapter 10. However, the repairs presented in Chapter 11 are unique and are presented to help a repair designer think through complex truss repair situations, not necessarily to provide a prescription of repair steps like the earlier chapters. This document presented both repairs that went well and those that had more challenges with the hopes that the readers of this course will specify effective truss repairs.

References and Notes:

- I first want to thank Mr. Mike Fuss PE for being a mentor and friend. There were many hours spent discussing truss repairs, and I have learned a lot from him. Thanks Mike!
- The repair sketches in this document were originally prepared by Ms. Christine Cavanaugh or Mr. Bryon DeGraw and have all been modified from the original truss repairs for this document.
- The truss designs presented in this document were all produced using the Engineering software and all repair sketches were made in the accompanying CAD software both developed by MiTek Industries Incorporated of Chesterfield, MO.

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