FIELD EVALUATION OF
CLINCHED CONNECTIONS FOR COLD FORMED STEEL

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Background

A major impediment to the use of steel framing which has long been recognized is the lack of cost-effective tools and fasteners to make connections quickly and easily. The Steel Framing Alliance has consistently identified tools and fasteners as one of the top priority research areas necessary to make steel framing competitive with other materials. Recent studies by HUD illustrate the cost impacts in this area. In *Steel vs. Wood, Cost and Short Term Energy Comparison: Valparaiso Demonstration Homes*, an extensive time and materials study showed a nearly $500 higher cost of fasteners on a steel home compared to an identical wood-framed home. Similar labor inefficiencies were recorded with the steel home, despite the use of experienced steel framers on the job.

One of the tool categories with promise is clinching. The PATH Technology Inventory describes "clinching" as a method of joining two pieces of sheet metal by pressing them together into a die that forms a connection. Fasteners such as rivets or self-tapping screws are not required with clinching.

There are several different clinching tools on the market, some described as portable, and others more appropriate for panel or factory operations. It is interesting to note that while clinching of steel framing is not a new technology, it is practically non-existent in the U.S. home building industry. In the mid-1990s, BHP Steel of Australia described various clinching techniques they use in steel-framing applications during an international conference held by IISI (International Iron and Steel Institute) in Maryland. Clinching is also more common in Europe.

PATH and the building industry are investigating why clinching has not been adopted in the United States, in order to improve this technology and thereby address the cost barriers associated with steel framing. This report addresses a pilot evaluation of one of the more-promising clinching tools at two PATH field evaluation sites in Hawaii.

Objectives of the Study

The primary objective of PATH Field Evaluations is to fill in the information gaps faced by members of the industry who need to make informed decisions on the use of a new technology. The specific questions about clinching technology addressed in this field evaluation are as follows:

1. What specific connections are appropriate for clinching of steel framing members?
2. Are there practical limitations with clinching on the job site? Are the tools relatively easy to use? What problems do the field personnel encounter in using them?
3. Are there benefits of clinching versus screws identified by field personnel? What improvements can the field personnel suggest to improve the tools and accelerate their adoption?
4. Are there significant code or design issues relative to steel framing connected by clinches rather than screws?

5. How much does the clinching equipment cost, and are there offsetting cost savings from the elimination of screws or from productivity increases?

Approach

Hawaii was selected as the location of the field evaluation because the area represents one of the largest markets for steel framing. This is driven mainly by concerns over termites and a large military housing presence. Thus, both the military and the private sector are using steel in high-volume production settings. Because of the large amount of steel framing, Hawaii also offered the ability to work with several builders and framing contractors in a short time frame.

Working with the Steel Framing Alliance, Newport Partners LLC identified builders and their framing contractors to participate in this field evaluation. Other tasks necessary to address the objectives of the field evaluation included:

1. Calls with product manufacturers to solicit interest and support.
2. Site meetings with the builders and framers to go over their operations and identify which applications are most appropriate for clinching.
3. Review of code and design requirements.
4. Training of crews in the use of clinching tools.
5. Observation of the crew's use of the tools in the selected applications to document difficulties.
6. Interviews of the framing crews and builders to determine their perceptions and experiences with the tools.
7. Assessment of quantities of screws saved and the costs of screw guns versus clinching tools.
8. Development of recommendations for manufacturers, framers, and builders based on the field trials.

Candidate Tools

Newport identified the manufacturers in Table 1 as those who produce clinching equipment that appears to have potential applications in steel framing. We contacted each manufacturer to assess their initial level of interest in the field evaluation and in the residential industry in general.

Table 1 – Manufacturers of Clinching Tools

Manufacturer Name	Location/Branch
Eckold	Germany
Trumpf	Germany/Connecticut
BTM	Michigan
Triton Industries	Illinois
Attexor	Switzerland/Massachusetts

Based on the availability of the tool and the manufacturer interest, we selected two tools manufactured by Attexor Inc., of Springfield, Massachusetts. Attexor is a Swiss-owned provider of clinching technology for a wide variety of applications including automotive, HVAC equipment, appliances, and construction.

Attexor makes a wide range of tools for clinching. Some are stationary tools that can weigh up to 60 lbs, while others are more mobile and weigh less than 8 lbs. The SPOT CLINCH® Compact 0302 and 0405 AS tools were selected for the evaluation. This line of tools was fabricated specifically for light gauge steel construction. The clinch is made through a punch and die set that is trigger-activated and powered by an air compressor with a regulated pressure of 90 psi. A hydraulic booster is used to increase the air pressure by a factor of about 60. Attexor has obtained an evaluation report from ICBO (ICBO Evaluation Report 5439**,** ATTEXOR SPOT CLINCH® Connection of Cold-formed Structural Members). The report provides details and performance data for clinching building frames, including applications in high wind and seismic areas.

Attexor clinching tool (left) and a hydraulic booster system (right) which powers the tool using compressed air. (Source: ATTEXOR Clinch Systems SA)

Participating Builders and Framing Contractors

The builders who volunteered for this project both panelize as much of the framing as possible. Thus, the evaluation was focused on the application of clinching in a panel facility. The first panel manufacturer is S&G Construction, of Ewa, Oahu. They are the panelizer for a large private-sector project being built by Haseko Construction. The second site was at the panel fabrication site of Hunt Building Company. Hunt builds homes for the U.S. military exclusively.

Site # 1 - Haseko Homes and S&G Construction

This evaluation was conducted on August 12, 2003 at a building site of Haseko Homes Inc. Haseko and their parent firm have more than twenty-five years experience in Hawaii. Their project is located in Ewa, Oahu in a development known as Ocean Pointe. Ocean Pointe is located on 1100 acres, and will eventually have nearly 5000 homes. The homes are built on slab foundations using steel framing for the walls and floors. The roof framing is wood trusses. The community includes other amenities such as a golf course, parks, walking paths, and a marina.

Haseko builds their homes by panelizing as much as possible off-site or nearby. At Ocean Point, a panel plant has been set up by S&G Construction. S&G produces the panelized components and provides them to a sister company who frames them for Haseko Homes. S&G has a similar relationship with at least one other large-volume builder in Hawaii where they have set up a panel facility at the building site. They have multiple stations at the facility including lines for panel assembly and off-line stations for fabrication of smaller components that go into the walls.

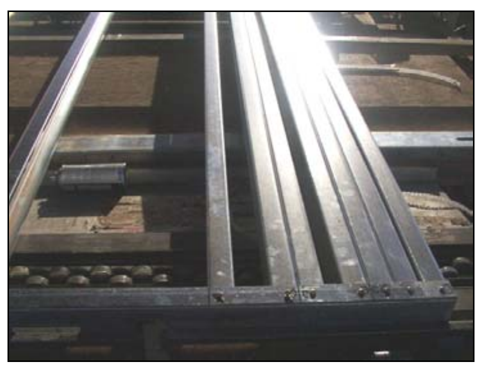
Steel-framed homes under construction at Ocean Pointe.

Newport spent the first part of the evaluation showing the laborers the set up for the clinching tool, explaining how it works, reviewing safety issues, and training the laborers on the proper use of the tool. With less than ten minutes of training, the framers became comfortable with the clinching tool. They were also given about a half hour to practice before using the tool in the production mode. In the observer's opinion, the framers became reasonably proficient with the clinching tool in a very short time period.

Wall panels under assembly at S&G facility.

Possible Applications for Clinched Connections

During an earlier visit to this site, Newport staff worked with the general manager of the S&G facility to identify a preliminary list of applications for clinching. One potential connection is at the attachment of wall studs to the top and bottom tracks. This connection accounts for a large number of screws in each home and it initially appears accessible from both sides for the clinching tool. One complication to this application is that walls include multiple double, triple and even quadruple sets of studs at point loads and openings. These members do not allow enough room for access of the clinching tool. The framer would be required to switch back and forth between clinches and screws. With the type of table that S&G uses, the wall section would also need to be flipped over to clinch each side of the stud. Their table has an integrated fastener system that applies the screws from the bottom. An alternative table set up could have been designed to allow access for clinching from both sides, but



Example of multiple studs that hinder access for clinching.

after consideration of the advantages and disadvantages, the S&G manager concluded that the stud/track connection was best made using screws.

Further observations of the panel activities and discussions with the S&G manager resulted in the identification of three other potential applications for clinched connections. In each case, the application consists of off-line activities where laborers build parts that are then used in the wall panels. These each consist of back to back sections, or doubles, of a stud to a track or a stud to a stud. The webs are connected to each other using screws at various distances, depending on the length of the double section.

Double Studs

The first section consisted of full length double studs used in the wall sections at openings. It is somewhat ironic that these are the same type of items that would hinder use of clinching the stud-to-track connection in walls. However, a single laborer works almost his entire shift fabricating these sections. This application was subjected to a time and motion study to compare screws versus clinches and identify opportunities for improvement. An interview was also conducted with the laborer to gather impressions of the tool and recommendations for improvement. The results of the time and motion study are discussed below, followed by a summary of the feedback and observations from the evaluation.

Multiple stud assemblies used at openings, point loads, and corners.

Work Sampling (Time-Motion) Study Using Clinches and Screws

Determining the "standard time" to perform a task is a valuable tool for identifying potential improvements in efficiency and in setting expectations for employees in conducting specific tasks. The most basic approach for determining standard times is to observe activities and record start and stop times. It makes sense to divide the activity under study into discrete subtasks and record the time required for each. With repetitive tasks, many observations, sometimes on the order of hundreds or thousands, can easily be obtained and lend themselves to statistical analysis. With others, a less rigorous approach can still result in valuable information.

During the field evaluation at S&G, a simplified time-motion study was conducted on back-to-back studs that are used throughout the home at corners and on both sides of windows, doors, and other openings. There were two major objectives for conducting the time-motion study:

- To determine a standard time for connections made with screws. This is of particular importance in determining the potential cost savings if screws were eliminated in a specific application.

- To determine a current baseline time for clinching. The primary purpose of this is to identify the relative time spent on each subtask and to isolate areas where improvements need to be made.

We use the term "baseline" time for clinching and "standard" time for screws for several reasons. First, a true work sampling, or time-motion study, should be conducted when the person being studied is operating under or close to optimal conditions. This is close to the conditions when the framer was using screws for the connections. The same case can not be made for the clinching because of the learning curve associated with any new technique, material, or tool; and because the tables and other parts of the set-up at the fabrication facility were optimized for use of a screw gun and not the clinching tool. Further, we recognize that clinching tools for site work are in their early stages of development. Part of the overall purpose of this field evaluation is to assess the current state of these tools for steel framing and to identify improvements that can help in accelerating R&D and adoption of clinching.

Back-to-back stud assemblies

The data associated with each subtask are included in the appendix. Although times associated with clinching and tools were determined, they should be used with caution for the reasons cited above.

One laborer was studied using both screws and clinches. He had been on the job for several years and his main task was to prefabricate parts later used in the main wall fabrication line. The application studied was back-to-back sections consisting of two full length 20 gauge wall studs with 10 screws spaced evenly along the length of the studs. The specific activity the laborer was working on was recorded every 15 seconds. A summary of the findings are shown in Table 2.

An analysis of the information in Table 2 is presented later in this report. Qualitative information was also collected during the study. Important observations during the study and comments during interviews with the framer are presented in the following sections.

Productivity

Productivity is closely tied to the number of studs the laborer carries from the stockpile to the fabrication table. During the trial, he made three trips for new studs each time. He carried 10 pairs during the clinching observations on these three trips and 15 during the screw observations. The laborer also was trying to show how quick he was with a screw gun and the observer felt he was putting more effort into the screws than into the clinches.

Table 2 - Data from Time-Motion Study

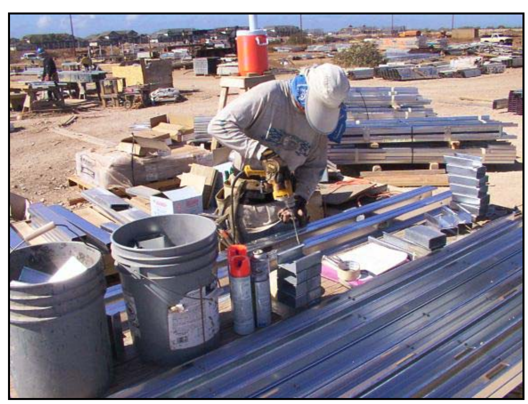
Clinching	Observations	
Get materials	6	
Orient materials in jig	8	
Clinch members	27	
Adjust clinching tools	14	(move tool along studs to next position)
Equipment problems		
Break/unproductive		1
Remove steel from jig	1	
Number of clinches	94 (9.4 pairs)	

Screws		Observations
Get materials	8	
Orient materials in jig	7	
Screw members	24	
Adjust screw gun	18	(Includes drops and placing screws into bit)
Equipment problems	1	
Break/unproductive		
Remove steel from jig	1	
Number of screws:	143 (14.3 pairs)	

Notes: The total observation period was 15 minutes for screws and 15 minutes for clinches. Each observation equals 15 seconds or four per minute. Missed observations in the charts are attributable to distractions from others on site who were interested in the clinching tool. The observer had to keep these interested parties away from the laborer who was under study. This resulted in three missed observations for clinching and one for the screws. Thus, increments do not add up to 60 for each. The number of missed observations is not considered significant for the purposes of this study.

Table Set-up

The table was designed for optimal performance with a screw gun. The supports of the table interfered with the ability to slide the clinching tool along the length of the studs. The tool had to be removed from the studs at each support and re-engaged on the other side of the support. The laborer suggested a simple saw-horse design could be used to minimize obstacles.



Left: The height of the bench required the user to bend forward and squat downward slightly while trying to position the clinching tool. Right: A framer uses his body weight to apply pressure to a screw gun.

The table is at the best height for using gravity to assist in installing screws. But this position (height) is counter-productive to the use of the clinching tool. The laborer felt a height just below chest level would be better with clinching since it would place the studs at about the same height of the clinching tool jaws when it is held with the arms bent to 90° and extended outward in front of the body.

Tool Flexibility/Weight

The laborer said he preferred to use screws. His arm tired quicker with the clinching tool and he had to bend over to engage it around the studs.

The Attexor Spot Clinch(r) 0405 AS was used for this application. This tool is heavier than the Attexor Spot Clinch(r) 0302 AS. However, the jaws of the lighter weight tool do not open wide enough to clear the flanges of the studs.

Laborer lifting the studs to slide the clinching tool past table supports. This requires him to hold the clinching tool with one hand and leads to tiring of the arm.

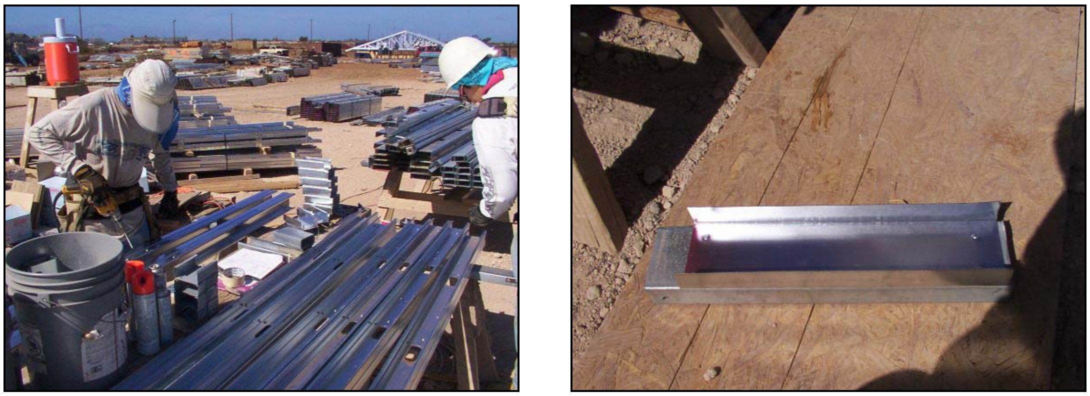
Back-to-Back Stud-Stud and Stud-Track Connector Members

In addition to the back-to-back studs, S&G has two other applications where laborers spend almost the entire day constructing back to back sections for connection of windows and headers.

The first of these connector sections is a short (about 6 inches long), 20-gauge stud attached back to back to a similar length of 16-gage track. Although the wider-opening, heavier Attexor tool will fit this application, the difference in material thicknesses posed a problem. The tool was tried to make sure it would fit into the space appropriately, but the specific punch/die set available for the clinching tool would not work with the 16 gage material. Attexor has punch/die sets that would work in this application but they were not available for this evaluation.

Wall section in home under construction. The short piece under the window opening connects the bottom of the window framing to the adjacent studs and is prefabricated "off-line" at the panel facility.

The other application is similar except the track and stud are both 20 gage and are longer (about 16 inches). Four screws, two at each end are used. A separate time-motion study was not done on this application since the attachment is very similar to the back-to-back stud application and the table set-up was not conducive to using the clinching tool efficiently. The biggest difference is related to how the materials are held in place. With the back-to-back studs, the longer sections require a large table with a lot of space to place the studs. On the track-stud sections, they are much shorter and don't require a special table. The track is placed over the open side of a full length stud to hold it in place. The shorter stud section is then placed with its web against the track web and held manually while the screws are applied. The track/stud is then removed and another pair is placed on the full length stud. Unfortunately, this set-up will not allow access to the underside of the track which is necessary for clinching.



Left: Laborers fabricating panel components off-line. Also, the table height is set for optimum performance with screws. Right: Stud to track assembly under study.

For the shorter back-to-back sections, the wider-opening, heavier Attexor tool was used. We conducted a qualitative assessment of the clinching tool versus screws on these sections. This included teaching the laborers how to use the clinching tool, letting them use it until they were comfortable with it, observing any difficulties they had, and interviewing them afterwards to obtain suggestions for improvements.

Overall, the laborers making these assemblies indicated that they would prefer to use clinching versus screws. One reason they cited was that the clinching tool was easy to use. It took only 10 or 15 minutes for the framers to get comfortable with the clinching tool itself. The biggest obstacle was not in making the actual clinch but rather in getting the tool properly positioned to be able to make a clinch.

Other issues raised by the laborers or by the observer are similar to those raised during the time-motion study of back-to-back studs. First, the table used for this application was at an appropriate height for screws but was too low for clinching.   The laborer was able to use his weight to apply pressure to the screw gun. With the clinching tool, the table should be higher, just below chest height, to reduce the bending and squatting the laborer needs to do to position the tool around the assembly.

Second, they would prefer to use the lighter Attexor tool. However, they believe weight would not be as large of a problem if the table were at a higher height, since it would be easier to balance the tool. They suggested a table set-up consisting of a short stud section that allowed the track to hang over each end so it pivoted around a central point. They could then set the track up the same way as for screws and turn the assembly as opposed to removing it and "flipping" it around. Another suggestion was to fix the clinching tool with a foot pedal to activate it. They could then move the stud/track assembly instead of the tool. They believe this may be quicker than positioning the tool for each clinch. Attexor confirmed that other framers are using their clinching equipment in a fashion similar to the methods suggested by the S&G laborers. The set-up includes foot pedal controls and multiple clinching heads where the steel sections are moved rather than the tool.

The use of a full-length stud to hold the track in place works well with screws but does not provide access for the clinching tool. The laborers were able to use the same arrangement by hanging the track over the end of the stud to provide access at one end, and then turning the assembly around to provide access at the other end for the clinching tool. The laborers believed the clinching tool was faster than screws for these shorter back-to-back sections, even with the need to flip the assembly to get access to both ends.

A new issue these laborers raised is related to safety. They think clinches are safer to use than screws. The risk of screwing your hand is removed (both have done this in the past) and there are no dust or chips generated. The chips can cause metal splinters in the hands and the dust and chips often gets blown into their eyes, even with safety glasses.

Like the other applications we observed, the laborers tend to drop about 10% of all screws. They seemed concerned about the waste being excessive but realized it was impractical to pick them up and either dispose of them or sort them to reuse the good ones.

Assessment/Conclusions

The quantitative data from the time-motion study should be analyzed with caution. It represents a relatively small number of observations. Given this qualifier, there are a few important points worth noting. First, the laborer was able to produce more finished stud pairs using screws versus clinching. He completed 14.3 screwed pairs versus 9.4 clinched pairs in the same time period, or about 50% more screwed pairs. By removing the time related to obtaining the members from the stock pile, the data show that the framer spent about eight seconds per clinch and just over five seconds per screwed connection. Increases in clinching productivity are expected if the table height is corrected to be more conducive to clinching and the table is built without intermediate supports that require repositioning of the clinching tool.

As noted previously, the laborer was clearly working rapidly with the screws during the time-motion study, but was not as hurried with the clinches. For example, he carried more studs per trip from the stock pile when using screws. This difference in effort is difficult to account for except by estimates of the observer. It appears likely that the differences in effort would bring the productivity of clinching much closer to screws and that the changes to the table and set-up would wipe out any differences in the productivity. In fact, previous attempts to compare the productivity of screws versus clinching, including a 1998 Cost Reduction Field Study Report by AISI, showed clinching to be faster than screws. Thus, we caution against concluding that screws offer better productivity over clinching or vice-versa. More detailed studies of productivity with multiple applications, laborers, and fabrication table arrangements would be needed to reach definitive conclusions on productivity.

Assuming the productivity is at least equivalent to screws, then clinching must provide other advantages over screws for the technology to be widely accepted. The cost savings from screws that are eliminated is perhaps the most readily quantified benefit of clinching. The screws used by S&G cost about $.035 each ($175 per case of 5000 galvanized screws). Based on the data collected in this study, S&G could save about $88 per shift on just the longer back-to-back stud assemblies. More details on the cost analysis and savings are provided later in this report.

Site # 2 - Hunt Building Company

Hunt Building Company typically builds homes for the U.S. Department of Defense. This site consisted of 70 homes for the Navy. The evaluation took place on August 11, 2003. Previously, Hunt and Newport had identified two potential applications: the stud to track joint on wall panels and the connection of angle connectors on the webs of floor joists.

Hunt recently purchased their own roll forming equipment to produce stud and track sections from a slit coil at the panel manufacturing site. The equipment not only rolls the shapes but also pre-punches holes at the location of screws for the track and stud connections in wall panels. Thus, there is no opportunity to use a clinch for this connection unless Hunt would adjust the roll forming equipment so that the screw locations are not pre-drilled. They indicated that they would be willing to do this if the clinching tool proved practical and cost-effective. Thus, the evaluation was conducted on studs and track that were not intended for use in the production of wall panels for actual homes.

Roll forming equipment used by Hunt Building Company

The second application was a short section of a joist and a 2-inch angle connector. For this application, the lighter Attexor tool would not fit over the end of the joist. Thus, the heavier tool that had a wider opening at the jaw of the tool was used. Although it fit over the assembly and could be positioned over the location of the clinch, the distance it had to reach caused the jaw to catch on the floor joist flange when the trigger for the tool was pressed. If the connector were located nearer the top or bottom of the joist, instead of the center, then the clinch would have functioned properly by accessing the connection from the end of the joist instead of over the flange.

Newport provided an overview to the participants from Hunt on the clinching tools. This included a short instructional session illustrating how to use the tools. The Hunt representatives were then interviewed to obtain qualitative feedback on the clinching technique and the specific tools. Observations and suggestions are as follows:

- The weight of the tool and the connecting air hose is too heavy. This could be mitigated somewhat if the tool were designed to be more balanced under use. In other words, most of the tool's weight is near the jaws, not the handle. Moving the handle to a position over top of the jaws was suggested as a way to provide a more balanced weight situation. Another suggestion was to provide a rotating handle that could be moved to various positions depending on the type of assembly being clinched. They also recommended a lighter hose to make it easier to move the tool.
- When using the tool, there is no way to know when the clinch is complete. This made them uncomfortable and slowed the process since they tended to hold the trigger for several seconds longer than necessary. It should be noted that Attexor has developed an add-on device they call an O-box that solves this problem. They describe the O-box as a controller that ensures an optimum clinching cycle time.

Overall, Hunt representatives were not sure clinching would be faster than screws from the limited time they worked with the Attexor tool, but they also recognized the cost of screws was a large expense for them and eliminating screws could make clinching worthwhile. They are being pressured to use stainless steel screws by the military and this will further increase the potential cost savings with clinching. Overall, they would switch to clinching if the manufactures would make some practical improvements, if they could meet code and design requirements, and if the cost of the tool were reasonable. They would consider changing their roll-forming process to eliminate the hole it punches in the studs and track if clinching proves viable. They believe more improvements would be necessary to make it feasible for their particular panel facility.

Wall studs with pre-punched holes used to align studs and as "starter hole" for screws.

Costs and Benefits of Clinches versus Screws

One of the more difficult economic evaluation tasks is to assess the costs and benefits of a tool and to allocate each to an individual home. On the other hand, the panel facility where the connections were studied represents a much more straightforward opportunity to assess and distribute costs and benefits. On the benefits side, we estimated the cost savings from screws that were replaced by a clinch by estimating the number of screws each laborer used in a given day, including dropped screws. Qualitative benefits such as increased safety were identified but not analyzed numerically. On the cost side, we collected information on the clinching tools, screw guns and various types of screws used for steel framing in Hawaii.

The screws used by S&G construction cost about $.035 each ($175 per case of 5000 galvanized screws). At the rates observed in this study, the framer would produce about 457 pairs of back-to-back studs each 8-hour shift. This amounts to 4570 screws or about one case per shift when drops or bad screws are included. However, the framing contractor confirmed that they actually produce a maximum of about 250 pairs per day and probably average about 225 pairs, which equates to about a ½ case of screws. Thus, the framer could save about $88 per shift on an average day. The difference in the observed rate of back-to-back stud production versus the lower number estimated by the framing contractor is consistent with the observer's belief that the laborer was working much harder with screws than clinches during the evaluation period.

For stainless steel screws, which are preferred by the military for steel framing in Hawaii, the cost of screws is more than twice that of galvanized, leading to a savings potential of around $200 per shift. Recently, the Navy has backed off on the use of stainless steel because of the negative interactions with galvanized steel. On the current Hunt project, the Navy approved the use of an enamel-covered or "ceramic" screw. There remains some uncertainty over which screws will be used in the future, although both alternatives cost about two times more than galvanized screws.

According to Attexor Inc, the tool used for the back-to-back studs and track connections retails for $10,200. This includes the entire set-up - clinching tool, punch and die set, pressure booster, and hose connector to the booster – except for the compressor and the pressure hose that connects it to the booster.

The cost of a screw gun used by S&G is roughly $100. A periodic tune-up, estimated to occur annually, costs about $25 per screw gun. The screw guns are often misplaced or stolen well before they wear out. S&G does not have documentation to support the life span of the screw gun. For this analysis, we only considered the first year costs of the screw gun and assumed at least a one year life span. In any case, even significant changes to the life span of the screw gun would not significantly change the results of this analysis because the cost of a screw gun is so small compared to the cost of screws and the clinching tool.

For the purpose of this analysis, we focused on the payback from screws that can be saved using clinching and the first year overall savings using a simple payback. It should be noted that the minor maintenance costs of the clinching tool, though not expected to be large, are unknown and could not be considered in this evaluation. The analysis is based on the average rate (225 pairs) of production confirmed by the framer rather than the higher rate (457 pairs) observed during the field evaluation. Thus, it may represent a conservative estimate of the benefits of the clinching tool. Results of the analysis are shown in Tables 3 and 4.

Table 3 – Cost Estimates for Screws and Clinches

Item	Clinching	Screws
Screws used per laborer per 8-hour shift		2500 including drops
Cost of screws (galvanized)		$175 per 5000
Cost of screws (stainless or enamel)		$350 - $400 Per 5000
Initial cost of screw gun including year 1 maintenance		$125
Initial cost of clinching tool and accessories	$10,200	
Clinching punch-die replacement	$750	
2 hp, 125 psi electric air compressor	$139	
3/8"x50' air hose	$10	
Electric power	See note below	See note below
Notes: Both the clinching tool and the screw guns require electric power. The cost of this power is relatively small for each and was not considered in the analysis. Also, incidental cost of smaller items such as extension cords and bit tips were not considered in our analysis. The main maintenance costs for the clinching tool are for replacement of worn punch/die sets. Periodic minor maintenance requirements for the clinching tool are unknown.		

Table 4 – Simple Payback Based on Different Screw Types and Cost Estimates from Table 3

Daily savings (galvanized screws)	Daily Savings (stainless steel or enamel screws)	Working days required to pay off initial cost of clinching tool (with galvanized screws)	Working days required to pay off initial cost of clinching tool (with stainless steel or enamel screws)
$88	$175 - $200	125 days	55 – 63 days

The cost savings from Table 3 indicate that the tool could pay for itself in about 25 work weeks with galvanized screws, or between 11 and 13 weeks with stainless steel or enamel-coated screws. The cost savings with stainless steel and enamel screws is expressed as a range because they are more variable than the galvanized screws. This probably is due to the more common use of the galvanized screws and a very competitive market.

After the time required for the tool to pay for itself, its use during the remainder of the first year would yield additional savings of about $11,000 to $39,000 depending on the type of screw being displaced. Keep in mind that there are some unknowns about the reliability of the clinching tool, the amount of down time that might be experienced, and that the analysis is based on five-day a week, eight-hour shifts operating 50 weeks per year. However, the annual cost of the clinching tool maintenance would need to approach the cost of a new tool for clinching to not be cost-effective.

This is a very unlikely scenario given the track record of clinching tools in other industries, including automotive and aerospace.

Another point to keep in mind is that this analysis only addresses some of the potential savings from clinching. It is unlikely that a contractor would invest in a clinching tool and limit its use to the one application we analyzed to determine benefits.

Code and Approval Issues

The use of any new material or technique introduces complexities into the building process that are often unexpected and sometimes include barriers that can't be easily overcome if at all. On the design side, the use of clinching should not pose insurmountable barriers, provided the appropriate supporting tests or analysis are provided by the manufacturer in a format acceptable to the designer and the building official. For example, Attexor has taken steps to secure an Evaluation Report from the ICBO Evaluation Service (ICBO-ES) that contains the allowable shear and tension loads for specific joints made with their tool. The report, ER-5439, is based on acceptance criteria for *Clinched Connections of Cold-formed Steel Structural Members* (AC137) previously issued by ICBO-ES.

For the immediate future, the use of the Attexor ICBO-ES report should provide a starting point for designers to use clinching. The allowable shear and tensile loads for clinches listed in the Attexor ICBO-ES evaluation report are generally lower than published loads for #8 x 1" screws. This means the designer may need to specify more clinches for some applications. Longer-term, the picture is not as clear because of the consolidation of the BOCA, ICBO, SBCCI, and NES evaluation services into the ICC-ES under the International Code Council (ICC). As of march 2003, new evaluation reports will only be issued by the ICC-ES, and the requirements of the ICC codes will serve as the basis for these reports. Evaluation reports issued by the pre-consolidation organizations are being carried forward by the ICC-ES as "legacy" reports.

It is not entirely clear what a legacy status means in terms of acceptance of the reports by code officials. It is likely that the reports will be accepted until communities begin to adopt the ICC codes and drop the individual BOCA, SBCCI, and ICBO codes. The adoption of the ICC codes requires action by state legislatures, city councils, or other law-making authorities. This process will take several years in most jurisdictions. In other communities it may be a much shorter time frame and 10 or more years in still other jurisdictions. In order to minimize potential barriers, it is in a manufacturer's best interest to obtain an ICC-ES report as soon as possible.

A related issue that could be a long-term barrier to clinching is the acceptance criteria for evaluations of products and technologies. If the code is not clear about what specifically is required for a technology or product, then acceptance criteria must be developed prior to issuance of an evaluation report. With clinching for cold-formed steel, the ICBO AC137 was issued in 1998 and updated in 1999. This criteria served as the basis for the Attexor evaluation report. However, the ICBO AC137 report falls into a similar legacy status as the Attexor Evaluation report, although the terminology used is "interim" as opposed to legacy. If Attexor or another manufacturer decides to apply for an ICC-ES report, it is likely that the evaluation criteria will need to be updated first.

To further complicate the situation, the ICC-ES "interim" acceptance criteria reports are divided into two categories. The AC137 falls into the second category, of which the ICC-ES website states the following: "The interim criteria listed below may be used as the basis for an ICC-ES legacy report, but they have been determined to be unsuitable for evaluations leading to a new ICC-ES evaluation report." Again, this suggests that the AC137 will need to be revised to meet the requirements of the ICC codes before an ICC-ES evaluation report could be issued to Attexor or any other manufacturer. The likely nature of the revisions is unknown.

The code requirements are important and in the case of clinching will be driven by the presence of currently-acceptable evaluation reports. Designers should likely be able to use the ICBO-ES Attexor report to incorporate clinching (using the Attexor tool) into structural components of homes built in the areas traditionally covered by the ICBO codes. The ICBO territory generally lines up with the areas where the use of steel framing is growing. This includes Hawaii, California and other high risk seismic areas and is one reason Attexor elected to obtain an ICBO-ES report rather than a report from one of the other code group's evaluation services.

Another opportunity for framers and builders is to consider clinching for non-structural purposes. For example, the attachment schedule of back-to-back stud sections at corners can be critical but is not necessarily so at openings or other point loads. In many cases, the screws or clinching schedules for non-structural components are somewhat arbitrary. The primary need is to hold parts together until they are installed in the final wall assembly. For non-structural connections, the designer could differentiate which connections are critical and which are not to enable the use of clinching.

Overall Conclusions

The use of clinching with tools similar to the Attexor line has immediate applications that appear to yield a high return on investment and a relatively short payback for steel framed homes, but only for certain applications characteristic of a panelization facility. For the applications we observed at a panel facility, the clinching tool could easily pay for itself in ½ year or less depending on the type of screw being replaced and generate thousands of dollars in additional savings throughout the remainder of the first year. This is probably a conservative estimate of the payback period because it is based on clinching of only one type of sub-assembly. Savings would be much higher in future years, although this would be controlled by the durability of the clinching tool itself.

The use of a clinching tool at the home site for steel framing is just not as practical as in the plant because of several limitations:

- The equipment is too bulky and heavy to move around a site.
- Access to both sides of an assembly is required and this is often hard to achieve on site. The tools are too large for many applications, or the use of double or triple members is so frequent that access is restricted.
- Both screw guns and clinching tools would need to be used, which would require switching back and forth between the two on the same assemblies.

- The tools are most effective at repetitive tasks rather than on the variety of connections encountered on a site.
- The tools require different punch and die sets for the vastly different metal thicknesses that are often found on site.

The most promising use of clinching is in a production setting where the same task is conducted repeatedly. A panel plant offers many opportunities for this. A good example is the fabrication of back-to-back studs that S&G uses at corners and at each side of door and window openings. These applications are ideal for clinching operations.

The participants agree that they need to have clearer information on the cost of clinching tools and their durability. They seem to be convinced that the potential cost savings in screws is significant and could justify an investment in clinching if a few practical improvements were made including:

- Making the tools and the hose lighter. It should be noted that Attexor is developing a compact, battery-operated clinching line that fits into a backpack to allow mobility.
- Balancing the weight of the tool so the center of gravity falls closer to the jaws of the tool. As an alternative, provide a handle that can rotate to shift the center of gravity depending on the position of the framer's hands relative to the assembly being clinched.
- Providing a jaw that opens wider and does not catch on the assembly when executing the clinch. A related comment was to increase user-friendliness by making the large opening position the normal setting. One participant suggested that some simple action, such as half pressure on the trigger, could be applied to partially close the jaws around the metal before applying full pressure to make the clinch. Releasing the trigger could then move the jaws back to the fully open position. This would eliminate the lever action needed to fully open the jaws on the Attexor clinching tool.
- Providing a means to know when the clinch is complete. As mentioned earlier, Attexor now offers a control device to address this issue. As an optional item, it adds about $700 to the cost of the system.

A final recommendation from the builders and framers – one that is obvious to the field evaluation staff as well – is that the tool manufacturers need to spend more time in the field with the framers in order to facilitate use of the tool in the proper applications. It is particularly important for the manufacturer to understand that the builder or framer has little time to conduct research or to experiment with innovations. Although there are opportunities to continually improve and expand the use of clinching at the panel plant and perhaps even during erection, this will not happen without the manufacturer taking an active role in the process. An investment of time is especially necessary in helping the builder or framer to get started.

As with any tool, Attexor and the other clinching manufacturers need to clearly understand the end user's needs and the product application in order to optimize the use of clinching and accelerate its adoption in the home building industry. The fragmented U.S. building industry (large number of relatively-small companies) does not have the infrastructure to support introduction of innovations except at a very slow pace. If the adoption of clinching is to be accelerated, the manufacturers will need to provide extensive support to the industry.

There are also recommendations for the framer and/or builder that would make clinching more practical including:

- Building tables specifically designed for clinching, including adjusting the height of the tables.
- Designing the tables for each application so that the clinching tools could be moved along a member to the next clinch without the need to completely open the jaw to move around table supports.

Next Steps for PATH and Tool Manufacturers

Probably the most important follow-on activity for PATH and the manufacturing community relative to accelerating the development and adoption of clinching for steel framing is to directly interact with the end users. The development of clinching tools needs to be closely tied to the activities in the field. Without closer interaction, some of the tools currently on the market but not well developed will not be accepted into the industry while others further along in their development will see limited and slow acceptance at best. With the first group, market resistance will be hindered because of significant limitations with the tools themselves. With the second group, including the Attexor tools used in this evaluation, there are also some limitations with the tools, but not enough to prevent their cost-effective use in several current applications within a panelization environment. The key to further adoption lies in working with the framer or builder to effectively integrate the tool into the production process. This is more than just providing the tool. It needs to include working with the builder on the home design, code approval process, optimal sequencing of tasks, and the design of work tables for fabrication of assemblies with clinches.

The framers and builders we visited under this evaluation, and dozens of other production builders interviewed recently for the Steel Framing Alliance on a related project, are pushing hard just to keep up with demand. They do not have the time or personnel to conduct extensive assessments of new tools nor to make major changes in their production process. This type of work needs to be performed “off-line” so as to not slow current production. The manufacturers will need to assist with the change process and often will need to take the lead. This short-term investment will result in accelerated growth of the market and will provide recommendations for improvements that will benefit users of the tools. PATH can play a role in this process with the manufacturers.

One way to assist is for PATH and the manufacturers to provide technical assistance to the top two or three potential users of clinching tools. The team should work with the builders or framers to optimize applicable framing operations for use of clinching. Once this first group is sufficiently along the learning curve, the technical assistance could be shifted to other candidates. An important thing to keep in mind is that this should result in a two-way flow of communications. Both the users and the manufacturers will benefit in the short-term. Ultimately, the benefits will be passed on to the home buyer.

Appendix: Time-Motion Notes

Crew description: One laborer studied using screws and clinches.
Application: Back-to-back, full-height studs used at corners and on ends of window and door openings. Pairs consist of two, 20-gauge studs with 10 screws spaced evenly along the length of the studs.

Date: August 11, 2003 Conditions: 80-85 degrees F. A few scattered clouds.
Observer: Mark Nowak S&G Contact: Jason Tashiro, general manager
One checkmark = 15 seconds.

Start time: 7:29 am **Stop time: 7:44 am**

Clinching	**person 1**
Get materials	6
Orient materials in jig	8
Clamp members	
Clinch members	27
Adjust clinching tools	14 (move along studs to next position)
Change tool/die set	
Equipment problems	
Break/unproductive	1
Remove steel from jig	1
Total clinches	94 (9.4 stud pairs)

Start time: 7:49 am **Stop time: 8:04 am**

Screws	**person 1**
Get materials	8
Orient materials in jig	7
Clamp members	
Screw members	24
Adjust screw gun	18 (Includes drops and placing screws into bit)
Equipment problems	1
Break/unproductive	
Remove steel from jig	1
Other:	
Other:	
Other:	
Number of screws:	143 (14.3 stud pairs)

Notes:

1. Missed observations in the table above are attributable to distractions from others on site who were interested in the tool. Observer had to keep these interested parties

away from the laborer who was under study. This resulted in three missed observations for clinching and one for the screws. Thus, increments do not add up to 60 for each.

2. The number of studs the laborer carries from the stockpile to the fabrication table varied during the study period. He made three trips for new studs each time. He carried 10 pairs of studs during the clinching observations on these three trips and 15 pairs of studs during the screw observations.
3. The laborer appeared to intentionally show how quick he was with a screw gun and the observer felt he was putting more energy into the screws versus the clinches.
4. The observer estimates the framer loses about 10% of the screws.