 

# Challenges in the identification and implementation of reference standards in gypsum board installation; a study of 20 projects.

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The aim of this study was to identify the prevalence of reference standards versus more subjective measures specified in projects by designers. The installation of gypsum board was used as a surrogate measure for overall adherence to quality standards. Twenty projects were identified and assessed for contract specifications in gypsum board installation. Specifications examined included pre-installation, installation, and finishing. Overall, 90% of projects, regardless of sector, referred to the established industry reference standard, ASTM C-840 as opposed to project specific tolerances. These findings have implications and can serve as a foundation for improved quality measures at the contractor and skilled labor levels.

**Key Words:** ASTM C-840, Gypsum Board, Quality, Tolerances

## Introduction

The construction industry struggles to implement uniform quality standards by adopting quality control systems that have been successful in other industries. Construction defects are costly and often are deadly. Contractors must address the issue of quality standards while facing skilled labor shortages and pressure by owners, regulators and sureties for higher standards.

A study by Zurich points to a trend by project owners to select only contractors having formal quality management protocols (Andrews, 2013). It has been ultimately recognized that the cost of poor quality, rework and time delays are passed to owners. The challenge exists for owners to engage contractors with formal quality programs in place. However, it is estimated that only 5 to 10 percent of United States contractors have a formal quality program (Andrews). Contractors without a quality management program adhere to the traditional idea that each project is unique and therefore quality is defined in real time. The belief is that each project utilizes a transient work force and established quality tools cannot be used efficiently. A Total Quality Management (TQM) implementation survey demonstrated that the top reason not to implement TQM was too much documentation and paperwork (Whiteman, 2004). Also cited was the difficulty in measuring results and the unique nature of each project

Traditionally, successful construction projects are delivered to the customer safely, on time, within budget and of high quality thus meeting or exceeding the overall specifications. Contractors define the quality of a project as meeting tolerances set forth in the plans and specifications (Whiteman, 2004). As the industry has advanced, drawings and specifications have become less precise. Designers have deferred to government standards, codes and regulations for tolerances leaving interpretation of quality to the contractor (Frank, 2012). A construction tolerance defines the allowable deviation from values given in the contract documents. These imperfections in measurements require the interpretation of work in degrees of accuracy thus resulting in the definition of allowable tolerances by industry standards and guidelines (Ballast, 2011).

In a United Kingdom study utilizing Weber's Law, consumers rated the quality of the installation of floor tile. It was discovered that joint width in tile varied by up to 70 percent before crossing the threshold of consumer acceptance (Forsythe, 2006). In this case, no uniform standard existed for "fit-and-finish" making interpretation of quality a subjective measure.

The intent of this study is to identify the tolerances provided by the design professional for the installation of gypsum board. As almost all projects involve the installation of gypsum board, it is hypothesized that this could serve as a surrogate measure for adoption of standard tolerances.

## Methods

Twenty construction projects were randomly selected from the Builders Exchange of Washington's virtual plan room (Appendix A). All projects at the time of the study were under construction or in the bidding phase. Four projects were classified as multi-use residential projects. The remaining sixteen were classified as light commercial projects. The scope of construction included residential apartment construction, new retail stores, office renovations and churches.

The study focus was on CSI 092900 gypsum board installation and finishing. Projects were selected to provide comparable data on several pre-selected factors. Reference standards cited by specification writer were identified in addition to other tolerances within the specification. Each project specification was analyzed for the standard used, pre-installation requirements and tolerances, installation requirements and tolerances, finishing and completed measures of success.

### *Reference standards*

Four main groups of reference standards and specifications concerning the application and finishing of gypsum board were identified: 1) the American Society for Testing and Materials (ASTM) C-840, 2) the Gypsum Association standard 216 (GA-216), 3) manufacturer instructions, and 4) other reference standards. Each project was reviewed to identify the presence (yes) or absence (no) of required reference standards in the specification section (Appendix B).

### *Pre-installation*

Pre-installation items were identified and noted for the following categories: 1) the pre-qualification for the installation company and the minimum number of years, 2) the requirement of "mock-ups" for inspection, 3) the minimum and maximum temperatures for installation, 4) framing and protrusions, 5) minimum bearing surface for gypsum board installation, 6) stud spacing maximums, and 7) plane maximum tolerance (Appendix B).

### *Installation*

Installation items included 1) environmental conditions- minimum and maximum temperatures and moisture amounts, 2) cutting and fitting tolerances, 3) designer specification of corner beads and tolerances, and 4) control joints and maximum spacing identified. Cutting and fitting tolerances were further delineated based on a) maximum spacing between sheets, b) finished floor, penetrations, and minimum board size, and c) identification of fasteners and specification of spacing. Where available, tolerances were noted (Appendix B).

### *Finishing*

Finishing items included 1) identification and the location of finish shown and 2) maximum flatness tolerances listed and specified for the completed system. Presence or absence and tolerances when available were noted (Appendix B).

## Results

Table 1

***Standards, Requirements, and Specifications by Project Type***

| *Reference Standards* | Residential | Commercial | Total (n) | Percentage (n/20*100%) |
|---|---|---|---|---|
| ASTM C-840 | 4 | 14 | 18 | 90% |
| GA-216 | 1 | 5 | 6 | 30% |
| Manufacturer's Instructions | 1 | 7 | 8 | 40% |
| Other | 1 | 6 | 7 | 35% |
| *Pre-Installation Requirements* | | | | |
| Installer Qualification | 1 | 4 | 5 | 25% |
| Sample Panel | 0 | 3 | 3 | 15% |
| Environmental Requirements | 2 | 2 | 4 | 20% |
| Frame tolerance mentioned | 0 | 6 | 6 | 30% |
| Minimum bearing | 1 | 3 | 4 | 20% |
| Max. framing distance | 0 | 3 | 3 | 15% |
| Framing plane max. | 0 | 2 | 2 | 10% |
| *Installation Specifications* | | | | |
| Board to board maximum | 1 | 5 | 6 | 30% |
| Penetration max. | 0 | 7 | 7 | 35% |
| Min. distance to FF | 1 | 6 | 7 | 35% |
| Fasteners specified | 1 | 3 | 4 | 20% |
| Spacing specified | 1 | 4 | 5 | 25% |
| Corner bead specified | 4 | 13 | 17 | 85% |
| Corner bead tolerance | 0 | 2 | 2 | 10% |
| Joint staggered required | 3 | 9 | 12 | 60% |
| Minimum board size | 0 | 4 | 4 | 20% |
| Control Joints | 2 | 12 | 14 | 70% |

*1*

*2*

## *3 Reference Standards*

Table 1 shows the results of analyzing the reference standards. All of the projects referenced at least 1 standard. ASTM C-840 was used as a reference standard in 90% of the selected projects including all of the residential projects. GA-216 was specified in 30% of the projects. Manufacturers' instructions were cited 40% of the time and "Other Reference Standard" was cited in 35% of the projects. Five of the projects (20%) included all of the standards listed above. One project listed three of the standards and two projects listed two of the standards. Eight projects (40%) only referenced one of the standards (data not shown).

## *Pre-Installation Requirements*

There was no consistent standard cited in the pre-installation specifications. In regard to installer qualification, four commercial projects and one residential project (25%) required the gypsum board installation company to have a minimum of 5 years experience. The requirement to have a sample panel was specified only in 15% of the projects. Environmental tolerances were listed in 20% of the projects. Other tolerances mentioned were framing tolerances (30%), minimum bearing surface (20%), maximum distance between framing members (15%) and acceptable tolerances for the framing plane (10%).

## *4 Installation Specifications*

Environmental requirements were not consistently specified in the selected projects with only 25% of the projects requiring a minimum temperature during gypsum board installation and finishing. Three projects specified maximum temperatures of 70-90 degrees Fahrenheit. Only one of the 20 projects identified a moisture requirement of the wall cavity of less than the 15% as specified by ASTM C-840. The data is illustrated in Figure 1.

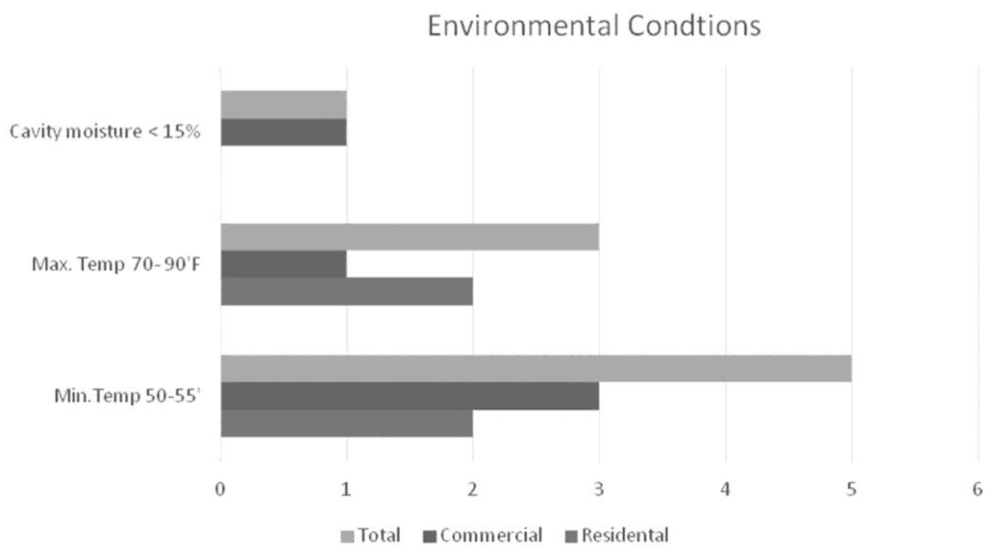


***Figure 1:*** Temperature Specifications During Installation

The requirement of corner bead installation was made in 85% of the projects but tolerances for the corner bead was only mentioned in 10%. Control joint location and types were the second most mentioned requirement (70%). "Staggered joints" was specified in 60% of the projects. Considering the long-term quality impact, fasteners and the spacing were only detailed in 20% and 25% of the projects, respectively. Cutting and fitting tolerances were mentioned in 30-35% of the projects. Using a minimum-sized piece of gypsum board of 8 square feet or larger was specified in 20% of the projects selected.

## *5 Finishing*

Finish level and location of wall finishes rated very high at 90% of all of the selected projects. Only 15% of the projects listed a tolerance for flatness that could be measured 1/8" in 10'-0".

## *Analysis*

Based on this study, construction tolerances were not specified by design professionals in any systematic way. However, use of reference standards is quite commonly used with ASTM C-840, the standard of choice. Cosmetics ranked highly with the mention of corner bead installation and the level of finish. Construction tolerances were rarely mentioned in the majority of the specifications. Mock-ups are only required on two of the twenty projects. There is a perception that residential type projects have less stringent quality requirements than their commercial cousins. However, these data indicate that they are similar with regards to specification tolerances.

Unfortunately, a contractor unfamiliar with ASTM C-840 would be at a disadvantage with respect to measurements of quality. The lack of ability to conform to ASTM C-840 standards would ultimately filter down to the supervisors, tradesmen and lesser skilled workers. Those involved in the project would be forced to rely on more subjective measures of tolerance and quality. Tolerance must therefore be uniformly drawn from the standard and applied. The likely measure of quality on most projects will be based on the designer's perception and owner's reaction rather than tolerances and standards.

## Discussion

There are two approaches to quality in construction; conforming to requirements of the contract and achieving customer satisfaction (Torbica, 2000). Typically, the industry prefers conformance requirements set in construction documents, building codes and zoning. This approach relies heavily on design and specifications to establish quality standards of measurement. Quality control is generally limited to retrospective inspection as a measure of compliance to standards. The customer satisfaction approach to quality is very complex and difficult to measure. According to Aft (1998, p.25), "because consumers do not always possess complete information about a product's attributes, they must frequently rely on indirect measures when comparing brands." Each customer's perspective of tolerance and quality makes this extremely challenging.

According to Fisk (2010), specifications are a detailed description of requirements, dimensions and materials intended to complement the drawings by defining the workmanship and procedures to be followed in constructing the project. Normally, architects incorporate in the specifications, a section containing a listing of "applicable standards" regardless of the project being constructed (Frank, 2012). Frequently, the architect is not aware of or has not read the whole standard; yet the contractor must ostensibly discover and know the requirements of a particular standard (Frank).

Traditionally, construction supervisors represented highly skilled specialized craftsmen. Contractors have relied on the contract documents to set forth the design specifications in measuring quality standards. In the absence of design specifications, construction tolerances were based on past experiences and professional judgment; complemented by an intimate knowledge of the materials and construction process. The current shortage of skilled workers creates a gap in continuity and a knowledge void. The average age of a skilled construction worker has increased from 37.9 years to 41.5 years, from 2000 to 2010 (Richey, 2013). According to a recent study, skilled trade workers ranked 4th in the top ten jobs as most difficult to fill in the United States and 1st in the world (Manpower Group, 2013).

It is implicit that supervisors should have a thorough knowledge of the quality standards relating to the work. There is a universal responsibility for compliance with industry standards but unfortunately, this does not guarantee understanding on the part of the contractor, the field superintendent or the foreman (Frank, 2012).

Manufacturing has shown that improvement in quality leads to increased productivity. A general reluctance to move to a quality management program in the construction arena has been blamed on the transient nature of construction workers and uniqueness of projects (Whiteman, 2004). It appears from this study that gypsum board installation standards are consistent across sectors 90% of the time. While the perception is that there is a lack of consistency of specifications between designers, it is apparent from this study that contractors can use the ASTM C-840 reference standard as a baseline for quality and tolerances.

## Conclusions

This study confirms designers do not provide detailed construction tolerances in drywall installation but refer the contractor to established reference standards. Contractors must not rely on the assumption that the designer's specifications will serve as the model for quality. Means and methods of construction are the contractor's responsibility but reference standards must be incorporated into their operation. Skilled workers can use tolerances; effectively increasing production output. A lesser skilled worker can perform self-assessments on in-progress work. But in reality, the specifications for quality are harbored in the reference standards and not in the subjective judgment of the designer or customer. With the acknowledgement of established, standard tolerances contractors can move forward with quality improvement tools similar to those used in the manufacturing industry.

This study is limited by its small sample size (n=20). In addition, all but one of the projects was located in the Northwestern region of the United States. Though randomly chosen, it is also possible that projects chosen were not representative of the Northwestern region of the US. It is also unknown if any of the same designers were involved in multiple projects thus creating a bias.

Gypsum board installation was chosen as a surrogate measure for tolerance and specifications because of the availability of reference standards and the almost universal need for gypsum board installation in most projects.

An avenue for future research will include an assessment of awareness and perception of reference standards by contractors and skilled tradesmen. An interesting facet to explore would be the relationship between awareness of standards and real time compliance and implementation of standards. In addition, the knowledge transfer of quality and standards to young tradesmen and construction management professionals newly entering the field can be examined to identify gaps in learning and professional development.

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## Appendix A
## Projects Selected

R-1 River Road Apartments, Eugene, Oregon
R-2 Foursquare Senior Living, Portland, Oregon
R-3 Lancaster Bridge Residential Rehab, Corvallis, Oregon
R-4 Beech Street Apartments (LWNW Project Network), Portland, Oregon
C-1 Interurban Office and Warehouses, Tukuila, Washington
C-2 QFC Store 831 North Shore, Tacoma, Washington
C-3 New Seasons Market, Portland, Oregon
C-4 Panda Express, Ontario, Oregon
C-5 Covenant Christian Community Church, The Dalles, Oregon
C-6 Rainier Beach Community Center Redevelopment, Seattle, Washington
C-7 WHH Nisqually Federal Services, Nisqually Markets, Lakewood, Idaho
C-8 Valdez Middle School, Valdez, Oregon
C-9 Helen Keller Elementary School Replacement, Tacoma, Washington
C-10 The Bellevue Botanical Gardens Visitor Services Project, Bellevue, Washington
C-11 Walgreens Store #12054 Bus 50 & SH 13, Warrensburg, Missouri
C-12 Ocean Shores Convention Center, Ocean Shores, Washington
C-13 Jack's Urban Meeting Place, Boise, Idaho
C-14 Walgreens Store #15158 State & 4th, Victorville, California
C-15 1222 E Pine Mixed Use Building, Seattle, Washington
C-16 Bellevue Youth Theatre, Bellevue, Washington

## Appendix B
## Results

| Project | R-1 | R-2 | R-3 | R-4 | C-1 | C-2 | C-3 | C-4 | C-5 | C-6 | C-7 | C-8 | C-9 | C-10 | C-11 | C-12 | C-13 | C-14 | C-15 | C-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Specification Section | 92116 | 9250 | 92900 | 92116 | 9260 | 92900 | 9250 | 9-2.A | 9250 | 92900 | 92900 | 92900 | 92900 | 92900 | 9250 | 9260 | 92116 | 92900 | 9.1 | 92000 |
| *Reference Standards* | | | | | | | | | | | | | | | | | | | | |
| ASTM C 840 | yes | yes | yes | yes | yes | yes | yes | no | no | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| GA-216 | yes | no | no | no | no | no | no | no | no | no | yes | no | yes | yes | yes | no | no | yes | no | yes |
| Manufacturer's Instructions | yes | no | no | no | no | no | yes | yes | no | no | yes | yes | yes | yes | no | no | no | yes | no | no |
| Other | yes | no | no | no | no | no | no | yes | yes | no | yes | no | yes | yes | no | no | no | yes | no | yes |
| Installer's Years Experience | 5 | no | no | no | no | no | no | | no | no | 5 | no | no | 5 | no | no | 5 | no | good standing | no |
| *Pre Installation* | | | | | | | | | | | | | | | | | | | | |
| Environmental Minimum Low | 40 | no | no | 55 | 50 | no | no | no | no | no | no | no | no | no | no | no | 55 | no | no | no |
| Maximum High Temp | 95 | no | no | 70 | no | no | no | no | no | no | no | no | no | no | no | no | 70 | no | no | no |
| Framing tolerance specified | no | no | no | no | yes | no | no | no | no | no | no | no | no | yes | no | yes | yes | yes | no | yes |
| Minimum bearing surface | firm | no | no | no | firm | no | no | no | no | no | firm | no | no | yes | no | no | no | no | no | no |
| Maximum distance framing | no | no | no | no | no | no | no | no | no | no | no | no | no | no | yes | no | yes | yes | no | no |
| Framing Plane maximum | no | no | no | no | 1/8" in 10' | no | no | no | no | no | no | no | no | no | no | 3/8 20' | no | no | no | no |
| *Installation* | | | | | | | | | | | | | | | | | | | | |
| Minimum Low temperature | 50 | no | no | 55 | 50 | no | no | no | no | no | no | no | no | no | no | no | 55 | no | no | 55 |
| Maximum high temperature | 95 | no | no | 70 | no | no | no | no | no | no | no | no | no | no | no | no | 70 | no | no | no |
| Cavity moisture | no | no | no | no | no | no | no | no | no | no | no | no | no | no | no | no | no | no | no | 12% |
| Cutting/fitting tolerance | | | | | | | | | | | | | | | | | | | | |
| Board to board | 1/16" max | no | no | no | no | no | no | no | no | 1/16" | no | no | 1/16" | 1/16" | no | no | tight | no | no | no |
| Penetrations max | no | no | no | no | 1/4" | 1/4-1/2" | 1/4-3/8" | no | no | 1/4 - 1/2" | no | 1/4"-1/2" | 1/4 -3/8" | no | no | no | 1/4" | no | no | no |
| Minimum distance to FF | no | no | no | 1/4" | 1/4" | no | no | no | no | no | no | no | no | 1/2 -3/4" | no | no | 1/4"-1/2" | no | no | no |
| Fasteners specified | no | no | no | yes | no | no | no | yes | no | no | no | no | no | no | no | no | yes | no | yes | no |
| Spacing specified | no | yes | no | yes | no | no | no | yes | no | no | no | no | no | no | no | no | yes | no | yes | no |
| Corner bead specified | yes | yes | yes | yes | yes | yes | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes | yes | yes | yes |
| Corner bead tolerance | no | no | no | no | no | no | no | no | no | no | no | no | no | yes | yes | no | no | no | no | no |
| Joint stagger required | yes | yes | no | yes | no | no | yes | no | no | yes | yes | no | no | yes | yes | no | yes | no | yes | yes |
| Minimum board size | no | no | no | no | no | no | 8 sf | no | no | 8 sf | no | no | 8 sf | no | no | no | no | no | no | no |
| Control Joints | no | no | yes | yes | yes | yes | yes | no | no | yes | yes | yes | yes | yes | no | yes | yes | yes | no | yes |
| *Finishing* | | | | | | | | | | | | | | | | | | | | |
| Level of Finish Specified | yes | yes | yes | yes | yes | yes | yes | no | no | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Mock-Up required | no | no | no | no | no | no | no | no | no | no | no | no | yes | yes | no | no | no | no | no | no |
| Flatness tolerance | 1/8 in 10' | no | no | no | no | no | no | no | no | no | 1/8 in 10' | no | no | 1/8 in 8' | no | 1/8 in 10' | no | no | no | no |