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Tolerances and Hold Points in Construction of Movable Bridges

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INTRODUCTION

This paper provides a general overview of tolerances and hold points in the construction of movable bridges. The paper explains what tolerances and hold points are, how they are established, who should establish them, and why they are important to the success of movable bridge projects. The paper presents the advantages of tolerances and hold points, ways to avoid ambiguous or unachievable tolerances, and how establishing tolerances and hold points is beneficial to both the contractor and the owner.

The paper presents case studies showing projects where either tolerances or hold points would have been beneficial to the project. All case studies have been sanitized to prevent identification of specific projects, engineers, contractors, and owners.

The intention is that this paper highlight a need for all of us to continue improving contract documents to allow for more accurate bids and better-quality construction projects.

TOLERANCES and HOLD POINTS

General

Tolerances and hold points in their basic form are easy to define. Tolerances are simply an upper and lower bound on a dimension, property or performance of a component, system or process. Hold points are pre-defined points at which an inspection is required, and the project cannot continue until the work has passed inspection. Establishing hold points and tolerances can be complex and requires experience in construction and manufacturing methods, engineering judgement and/or analysis.

For movable bridge mechanical and electrical work there is essentially no guidance on hold points and limited guidance on tolerances in the applicable highway and railroad governing standards including the AREMA *Manual for Railway Engineering* and the AASHTO *Standard Specifications for Movable Highway Bridges.* As a result, engineering firms, engineers, and owners are left to decide what is acceptable with respect to hold points and tolerances. Often, hold points and tolerances are not well defined in the contract documents, do not cover all items or are omitted all together. In some cases, tolerances that are provided are not achievable.

When requirements on the contract documents are not clear or cannot be achieved, the contractor and the manufacturers are required to make assumptions based on experience with similar projects, owners and engineers. Assumptions equate to risk and contractors' price in risk when estimating project costs. Therefore, project costs increase when sufficient information is not provided. Unknowing contractors may bid low only to find out that expectations are higher than expected which in turn leads to increased costs that were not accounted for. Regardless, a lack of information on hold points and tolerances can be problematic to all involved parties.

Tolerances

Tolerances on movable bridge projects typically relate to dimensional tolerances but may also relate to systems or processes in some cases. This paper is limited to the general discussion of dimensional tolerances. Dimensional tolerances relate to fabrications and machined parts as well as global position and alignment tolerances related to the field installation of machinery parts and of the structure itself.

Tolerances define acceptable variations in parts, allow for parts of an assembly to fit together properly, serve to ensure that parts are interchangeable, and ensure that the bridge is located within specified limits. Parts that do not have correct tolerances may not function as intended or may not work at all. While the AREMA and AASHTO publications provide guidance on fits which effectively define tolerances for many parts, these standards do not provide tolerances for some parts and there is little if any guidance on alignment or global position tolerances. These undefined tolerances are left to the engineer to figure out. Often these tolerances are not provided by the engineer in the contract documents or are ambiguous and left to interpretation. This ambiguity can lead to problems during construction.

Defined tolerances provide a dimension or orientation and the acceptable variation in the dimension or orientation. Acceptable variations can range significantly depending on the function of the part and typical manufacturing methods for the part. Parts that are fabricated typically have larger tolerances than machined parts because the manufacturing methods (cutting, burning, welding, etc.) are not accurate enough to allow for tighter tolerances. Parts that are machined (turned, milled, bored etc.) can be made to much tighter tolerances than fabricated parts.

To specify the correct tolerance, the engineer needs to understand the function of the part and then must select or at least understand the manufacturing method that can achieve the desired tolerance. The larger the tolerance, the lower the cost and therefore the knowledge of tolerances and associated manufacturing methods is important and of value. Parts should be specified to the largest tolerance that achieves the specified result.

In the case of field installations, tolerances are typically associated with alignment or the global position of the structure. The engineers' knowledge is key to providing tolerances that allow the structure to function properly while being achievable with available construction methods. Failure to properly define tolerances can increase costs or lead to systems that do not function as intended.

Terminology associated with alignment and position (including distance, elevation, level, plum, in-line and square) needs to be specified along with a tolerance. It is of no value to use these words without an associated tolerance. Likewise, words like "perfect alignment", "exact" and "equal" should be avoided. In the world of measurements "perfect", "exact" and "equal" are not achievable.

Currently most global and alignment tolerances are left to the engineer to determine what is acceptable with no industry standards on which to rely. For instance, what is acceptable gear tooth contact? Chances are the criteria will be different depending on the engineer, yet the function is the same. The same is true for the absolute position of a bridge. Is it necessary for a bridge to be located within 1/16" relative to earth? Probably not. Having well defined acceptance criteria that are standard for the industry and not based on one engineer's judgement would be beneficial and should result in better built or at least more uniformly built structures.

Tolerances provide important information to the contractor, and they provide measurable acceptance criteria throughout the contract. As an example, the tolerances for the alignment of the trunnions on a bascule bridge may dictate certain construction methods and measurement procedures and this needs to be built into the contractor's price for the work. In the case of acceptance criteria, if measurable tolerances are provided, it is clear as to whether an item is acceptable and meets the contract requirements. There is no gray area. Conversely if two items are specified to be "equal" with no tolerance provided, and one part varies by an insignificant amount, someone might suggest that they are not equal and expect either replacement or some other form of compensation. However, if they are specified to be equal within a specified parameter the ambiguity is avoided and the items either meet the requirement or they do not. Things change throughout construction, and it may be found that a specified tolerance is no longer acceptable or perhaps the specified tolerance is not correct. When this is the case and there are cost implications, the owner needs to recognize that these costs should not be borne by the contractor. Likewise, when parameters are relaxed and there are cost savings, the contractor should pass these on to the owner in some fashion.

In order to avoid potential confusion and conflicts during construction of a movable bridge, the engineer should provide measurable acceptance criteria and define the following on the drawings or in the specifications:

- Fits and finishes for all parts in accordance with the governing standards
- Tolerances and surface finishes for parts not defined by the governing standards such as:
    - The OD and ID of segmental girders and tread plates
    - Trunnion to trunnion alignment
    - Machining requirements for structural components that support or mate with machinery parts
- Measurable alignment criteria for journal bearings including trunnion bearings
- Gear tooth contact requirements
- Position of components relative to the structure or foundations
- Position of components relative to each other

Hold Points

Hold points or stop points in construction are milestones on a project where the work completed to date is inspected and verified to be conforming or non-conforming. If work is conforming, then construction can proceed. When work is non-conforming, corrections are required and work only proceeds after the necessary corrections are made.

Hold points stop the progress of work and therefore hold points need to be well defined in the contract documents to avoid project delays. Hold points can lead to project delays for several reasons as follows:

- Undefined hold points enforced during construction
- Deficient or incomplete work
- Challenges to acceptance criteria
- Delays in the inspection of completed work
- Delays in the review of submitted inspection data

Some of these causes of delay are under the control of the contractor while others are not. Clearly defining required hold points, inspection requirements, enforcement responsibility and time allocated for each of these items should be well defined in the contract documents so that work is not unnecessarily delayed.

Hold points are typically used when work that has been completed will be covered up or when it would be difficult, impractical, or costly to make changes after the next steps in the process take place. A typical hold point that is often cited is the verification of rebar prior to pouring concrete. Once the concrete is poured it is impractical and perhaps impossible to verify size and spacing without destructive testing. Therefore, checking the rebar prior to pouring the concrete is necessary and makes sense.

In residential construction, hold points are common prior to pouring foundations or footings, and after framing, plumbing and electrical installations are complete. Again, this makes sense since verifying plumbing and electrical installations after drywall is installed is not practical. In fact, these hold points are required by most if not all local authorities. You simply don’t proceed until these installations have passed inspection. Again, this makes sense. In addition, these inspections protect all involved parties including the homeowner, contractor and perhaps to a lesser extent the public.

In movable bridge construction, hold points are not typical even though movable bridge construction costs can be orders of magnitude greater than the cost of a typical house and the cost of making repairs and the associated delays are far more significant as well.

If hold points are beneficial in other sectors of construction, it seems reasonable that hold points would be beneficial in the construction of movable bridges. In fact, hold points are beneficial and should be used when constructing or rehabilitating a movable bridge.

The discussion of hold points in this paper is limited to components of the bridge that impact the operation of the bridge.

Neither AASHTO, AREMA or the CHBDC mention hold points in construction and other governing specifications are generally silent on hold points as well. Until governing agencies adopt and enforce hold points it will be up to the owner, engineer or the contractor to establish hold points on movable bridge projects.

Most owners rely heavily if not entirely on the engineer they hire to prepare contract documents including plans and specifications for movable bridge projects.

Some engineering firms have significant experience in the design and construction of movable bridge projects and have been involved with many movable bridge projects while others may be preparing plans and specifications for a movable bridge project for the first time. Some contractors have significant experience with movable bridge construction and have been involved with many movable bridge projects while others may be bidding their first movable bridge project and are looking to get into the movable bridge construction market.

Owners typically have significant control over the selection of the engineer they hire, and it is incumbent on the owners to do their due diligence when selecting an engineer for a project as complex as a new movable bridge or the rehabilitation of an existing movable bridge. Owners should take this job seriously and hire a firm or a team of firms with the necessary experience to prepare a high-quality set of plans and specifications.

Often owners have little control over the selection of contractors as the selection of a contractor is left to the low bid process. Private owners including railroads may have more control over the selection of contractors and can limit opportunities to those contractors with a proven track record in the construction of movable bridge projects.

There is a wide range of experience in the industry. Some engineers and contractors may be fully capable and appreciate the need for establishing hold points throughout a construction project while others may not. There is a wealth of knowledge in the industry and the best approach to developing hold points is to have owners, engineers and contractors work together to develop hold points that make sense. For the time being it is probably best that the engineer determine what hold points are necessary and clearly identify these hold points on the plans or in the specifications. Enforcement of hold points is the responsibility of the owner or the owners' representative.

Deciding on hold points after a project is awarded is a possibility but comes with risk. The risk being that the contractor will not agree that holds points are necessary and that the necessary inspections at hold points are causing delays and are increasing the cost of the project. The contractor may be justified in claiming an extra if the hold points are not fully defined in the contract documents.

Inspections are a necessary part of hold points in construction. For hold points to work, inspections need to be timely and effective. The contractor needs to provide sufficient advance notice of completion, and the owner needs to provide prompt and thorough inspection of work that is completed. There should be a formal sign off on hold points.

CASE STUDIES

The following is a presentation of several case studies to demonstrate how tolerances and hold points were used or could have been used to benefit the project.

Case Study 1 – Swing Bridge

Balance Wheel Track

- Balance wheel track diameter: 24 ft.

Specified clearance at balance wheels: 1/32" to 1/16"

- Measured change in diametrally opposed balance wheel clearance: 0.278" during bridge opening
- Surveyed track elevation variation: 0.175" (max variation = 2 x.175"= 0.350).

Based on the measured balance wheel clearances and the survey data, we found there was no way to achieve the specified balance wheel clearance without leveling the track. Preferably the track would be level to plus/minus 1/64" to meet the tightest tolerance of 1/32" clearance at each balance wheel for the full range of bridge motion. A tolerance on the level of the track was not provided in the contract documents.

The source of the out of level condition was not determined but may have been due to improper installation or operating the bridge on the track with a severe imbalance prior to grouting the track and thereby deforming the balance wheel track.

Unfortunately, this problem was discovered after the track was grouted in place. The only options to achieve the required balance wheel clearance were:

1. Replace the balance wheel track
2. Chip out the grout and level the existing balance wheel track
3. Machine the balance wheel track in place

Options 1 and 2 were not considered practical and option 3 was selected as the method to achieve the specified balance wheel clearance.

The contractor proceeded with machining the balance wheel track and was able to meet the specified balance wheel clearance after machining was complete and the balance wheels were shimmed.

This repair option caused significant delays and significant cost.

The following should have been considered when putting the contract documents together.

1. Providing a direct tolerance for the elevation of the balance wheel track in the contract documents. The documents did provide a balance wheel clearance, but it would have been far clearer if the final elevation tolerance of the track had been provided.
2. Specifying that the bridge is not operated until it is properly balanced, and the balance wheel track is fully grouted.

3. Specifying that the balance wheel track is not grouted until it was level within a specified amount.

Had these items been provided in the contract documents, this problem may have been avoided.

Case Study 2 - Swing Bridge Balance

Span Balance

As part of measuring balance wheel clearance and monitoring the balance wheels during bridge operations, it was apparent that the bridge was out of balance. Testing was conducted to determine the out of balance condition. This testing consisted of withdrawing all wedges and then adding weight to the bridge deck until the span tipped in the direction of the weight and then calculating the moment based on the known weight and the distance to the weight. This provided a rough magnitude of imbalance.
The testing yielded the following results:

Transverse imbalance: 350,000 ft. lbs.
Longitudinal Imbalance: 7,000 ft. lbs.

The longitudinal imbalance was relatively small however the transverse imbalance was significant and equal a reaction of over 29,000 lbs. at the balance wheels.

When the imbalance was discovered, the bridge was substantially complete including the cast-in-place concrete deck. The only practical solution to the balance problem was to add weight to offset the imbalance moment.

The balance was corrected by adding steel plates to the bottom flange of one girder and to one end floor beam. The total weight required to balance the bridge was approximately 24,000 lbs. Since this work was not planned, it resulted in additional cost, and delays to the project.

No forensic work was conducted to determine the source of the imbalance problem.

Had hold points been specified in the project documents it is likely that the imbalance problems could have been resolved early in the project. The following should have been considered when putting the contract documents together.

1. Requiring detailed balance calculations.
2. Specifying an imbalance for the completed structure. It is not clear if a balance specification existed, however we were not provided with a specification.
3. Requiring interim balance measurements throughout construction.

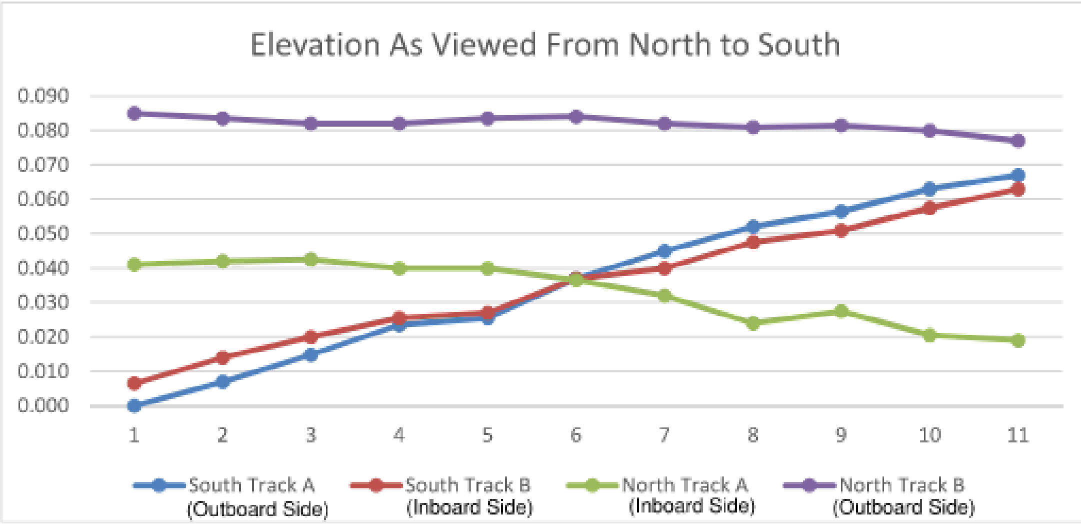
Case Study 3 - Single Leaf Rolling Lift Bascule

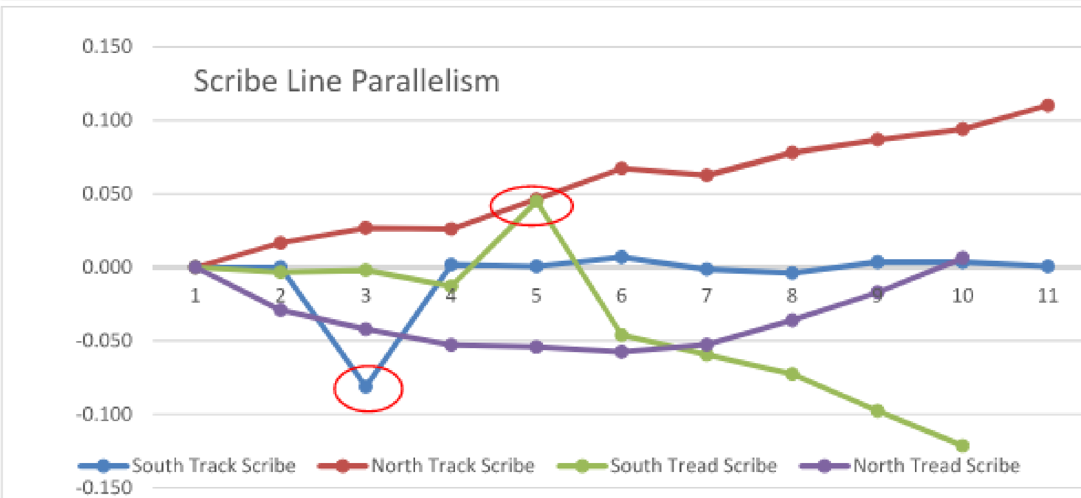
Tread and Tracks

Tracks and tread plates survey data submitted by the contractor for the installed tread plates was questioned by the engineer of record as there were concerns that the “as surveyed” conditions could result in poor contact and rubbing wear. The following conditions existed at the time of survey:

- End to end elevation of the track plates varied by 0.085"
- Elevation across the width of the track plates varied by 0.067"
- Track plates were not parallel by 0.110" over their length
- Tread plates out of parallel by 0.121"

- The following graphs show the survey data (vertical axis dimensions are in inches, horizontal axis are uniformly spaced stations along tracks):





The project specification provided the following alignment information:

- “Set the tops of the tracks at the exact elevation called for on the plans, and align them so they are perfectly level and all in the same horizontal plane. Centerlines of the track castings must be the exact same horizontal plane. Centerlines of the track castings must be the exact distance apart and parallel to the longitudinal centerline of the bridge”
- “It is imperative that the tracks are set to nearly perfect alignment prior to further construction; otherwise, the proper operation of the bascule span cannot be assured”
- In addition to these statements, a tolerance of within 1/32" was provided for some features.

Although this language expresses the importance of alignment, it does not provide tolerances for all features for the contractor to bid the work accurately nor does it provide tolerances for acceptance. There is also the suggestion of a hold point but there are no required hold points.

Had hold points and tolerances been specified in the contract documents it would have been possible to stop construction at appropriate times to verify that the installation conformed to the requirements of the contract documents. Using words like exact and nearly perfect are subjective and do not provide a basis for acceptance or rejection. Who decides what is perfect?

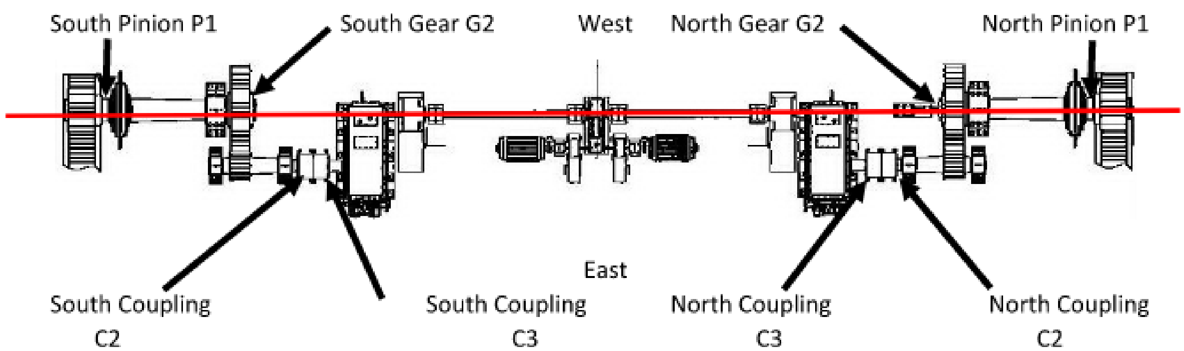
Case Study 4 - Single Leaf Rolling Lift Bascule

Rack Pinion Shaft Alignment

The rack pinion shaft alignment on a rolling lift bascule bridge is largely dependent on the alignment of the two bascule girders relative to each other. The rack pinion shafts need to be square to the bascule girder and in-line at the center of roll to track properly along the racks. This was specified in the contract documents based on the following statements:

- Align the pinion shafts so they are square with the treads and collinear to within ±1/64 inch of the wire."
- The centers of roll were specified to be within 1/32"

Initial alignment measurements using a laser tracker showed that the rack pinion shafts were not well aligned to each other. The following shows initial alignment data.



Dimensions in the tables for this case study are in inches.

Perpendicularity With Respect to South Track Scribe Line

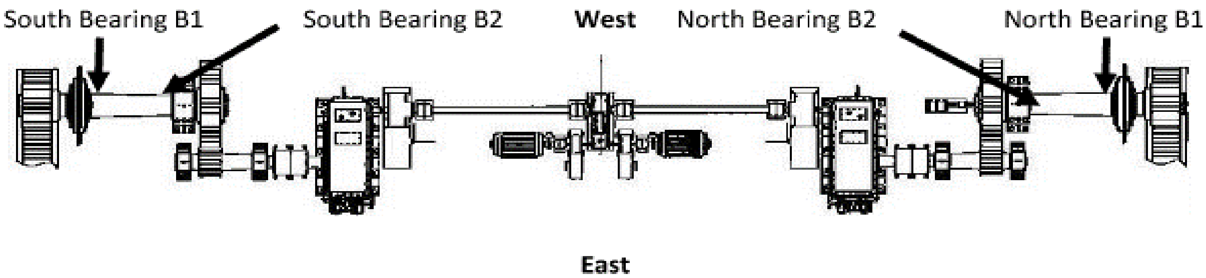
P1	G2		G2	P1
373.968	373.935	Nominal From Origin Point	373.792	373.736
0.000	-0.033	Zeroed at South P1	-0.176	-0.232

Elevation With Respect to South Track and A Level Plane

P1	G2		G2	P1
295.263	295.371	Nominal From Origin Point	295.341	295.250
0.000	0.108	Zeroed at South P1	0.078	-0.013

The data demonstrates that the rack pinion shafts are significantly out of square relative to the south track scribe line. Adjusting the line so that it passes through both P1 locations shows that the rack pinions shafts were not colinear to within the requirements of the contract documents.

Survey data from a later date shows that the rack pinion shafts were not collinear as shown below. No attempt was made to correlate the data from the two surveys.



Initial Measurment taken on 2-20-17

South			
Bearing	B1	B2	
X	0.000	0.040	
Y	0.000	-0.176	Delta Z
Z	0.000	66.542	66.542

	North		
	Bearing	B1	B2
	X	0.000	-0.049
Delta Z	Y	0.000	-0.187
66.237	Z	812.866	746.629

X – Horizontal, Y-Vertical, Z - Transverse

At this point in construction there was no ability to use piano wire as machinery was in the way. A laser tracker was used to generate the data shown. Based on a specified tolerance of 1/64", the rack pinions shafts did not meet the requirements of the contract documents.

The B2 bearings were adjusted to provide collinearity of the rack pinion shafts within the specified tolerance for collinearity. The following are the final alignment values.

Final Measurment taken on 2-23-17

South			
Bearing	B1	B2	
X	0.000	0.000	
Y	0.000	-0.001	Delta Z
Z	0.000	66.340	66.340

	North		
	Bearing	B1	B2
	X	0.000	0.004
Delta Z	Y	0.000	-0.001
66.142	Z	812.895	746.753

X – Horizontal, Y-Vertical, Z - Transverse

The final measurement data was extrapolated to the ends of the pinion shafts and the shafts were found to be within the requirements of contract documents.

The corrections made to improve collinearity did not address the out of square condition. When comparing the movements to achieve collinearity from the two tables above with the perpendicularity data it can be shown that a significant out of square condition remained. There was no practical way to correct the out of square condition at this point in the construction.

The B2 alignment changes impacted the open gear alignment and necessitated changes to the racks and to the B3 and B4 bearings to obtain satisfactory gear tooth alignment. Since this machinery had been permanently installed at the time of the B2 alignment changes, significant and complex rework was required.

Rework to correct the rack pinion alignment included detailed measurements to establish existing alignment and shimming and realignment of the rack segments on a section-by-section basis to obtain satisfactory alignment. This work included the installation of custom tapered shims at each rack segment and the installation of new larger turned bolts.

The effort required to obtain satisfactory alignment was significant and required several weeks of field work in addition to delays and costs associated with material procurement.

The rework of the B2, B3 and B4 bearings varied but was complex and time-consuming. Movement of the bearings required an increase in bolt diameter to maintain the required bolt fit and to avoid "snowman" holes. In some cases, the oversize bolts resulted in insufficient edge distance. In these cases, chocks were installed with turned bolts to secure the bearings against movement.

In addition to the work required by the contractor to correct the deficiencies, significant engineering was required to document existing conditions, to develop appropriate repairs and procedures, to oversee the work on site, and to document final alignment conditions.

Our involvement with the project took place over a period slightly more than a year and required more than 1,400 hours of engineering.

The lack of hold points on this project proved to be a major problem. Most of the work was thought to be complete when alignment issues were discovered. As a result, complex, tedious and non-standard methods were used to achieve satisfactory alignment. Had hold points been required and enforced, many if not all the problems could have been avoided.

Case Study 5 - Shop Inspection

45" Outside Diameter Rack Pinion

This job involved the replacement of a large rack pinion on a bascule bridge. The existing pinion was severely worn, and the center distance was not correct resulting in too little pinion engagement. The pinion was replaced with a special pinion with a modified tooth profile to work better with the incorrect center distance.

The shaft on which the pinion was mounted was large and had another large gear mounted on it. To get the shaft off the bridge to ship to the shop for removal of the existing pinion and installation of the new pinion, a section of sidewalk had to be removed.

The pinion was successfully installed in the shop. Then the shaft was installed on the bridge and the sidewalk closed.

There was no shop inspection of the new pinion in the shop.

Sometime later it was noted that the pinion had excessive wear, and the bridge owner was concerned that there was a problem.

Photos sent by the owner showed that the profile of the installed pinion was not the same as the profile on the shop drawings. Subsequent field measurements showed that the pinion teeth were not correctly machined.

It was discovered that the manufacturer made the pinions using an out of date drawing and not the latest revisions to the drawing.

The pinion was replaced with a new pinion meeting the requirements of the latest drawing revision.

This case study demonstrates the importance of shop inspection for machinery and other parts. A qualified inspector with access to the latest drawings could have determined that the pinions did not meet the requirements of the drawings. Had the issue been identified in the shop there would have been delays to the project, however the work associated with the installation and removal of the improperly machined pinion would have been avoided.

Case Study 6 - Tolerances

General

This was a job where we provided construction services to the contractor, and we were involved with the project from the bid phase through the end of construction. When reviewing the design drawings prior to the bid, we were concerned that some of the required alignment tolerances were not achievable and could be a source of conflict during construction. Three examples of tolerance issues are cited below.

Trunnion Shafts

The following trunnion alignment requirements were provided on the design drawings:

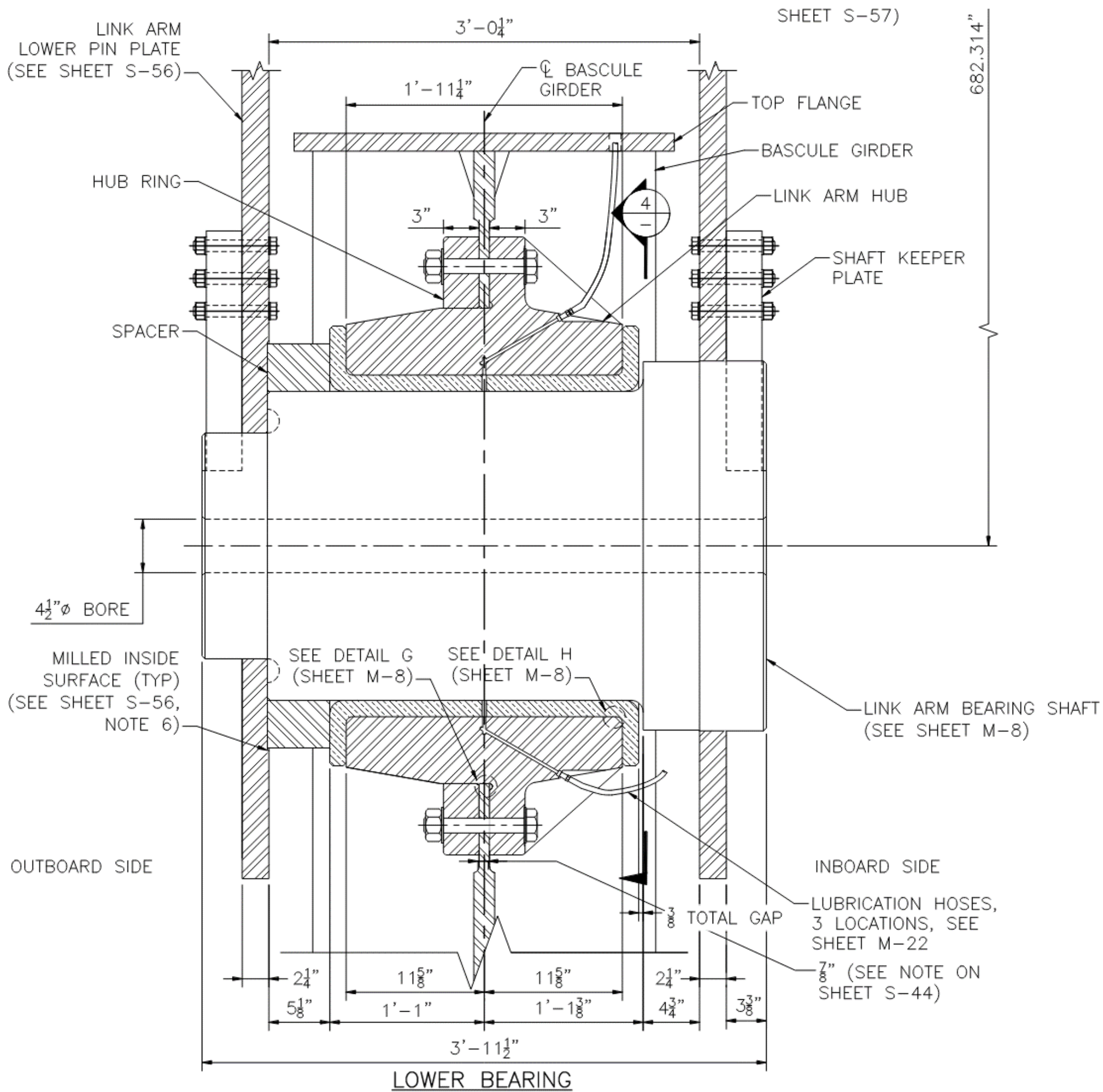
- Each shaft elevation shall not deviate more than 0.001"/foot from the horizontal plane
- The average elevation of each trunnion shaft shall not deviate more than 0.005" from each other.
- Counterweight trunnion shafts shall be collinear to each other. The contractor shall measure at each shaft end and align the collinearity to be within 0.006"

These were the tightest tolerances we had ever seen on a movable bridge. The tolerances were well coordinated but we felt they were not achievable. This is based on the following:

- A typical machinist level is graduated to 0.005"/ft. This is far less than the required accuracy of 0.001"/ft.
- The most accurate instruments we are aware of are accurate to +/- 2 arc seconds. This is approximately +/- 0.009" over the distance between the trunnions on this bridge. This is the accuracy of the instrument and does not consider other sources of error in measurement. The instrument error alone is greater than the specified tolerance.
- Temperature variations impact the measurements. The steel towers that the counterweight trunnion bearings were mounted on were approximately 50 ft. tall. A 1-degree Fahrenheit change in temperate changes the height of the tower by 0.004" or nearly all the available tolerance on elevation.
- Typical colinear tolerances on movable bridge projects are 0.020". This has proven to be achievable but with some difficulty. The specified tolerance was more than 3 times tighter than the typical tolerance.

Link Arm Bearing Shafts

The link arm bearing shafts had the same requirement for level as the trunnion shafts. In addition, the shafts were required to be parallel to the trunnion bearing shafts within 0.010" per foot. Pictured below is the detail for the lower link arm shaft.

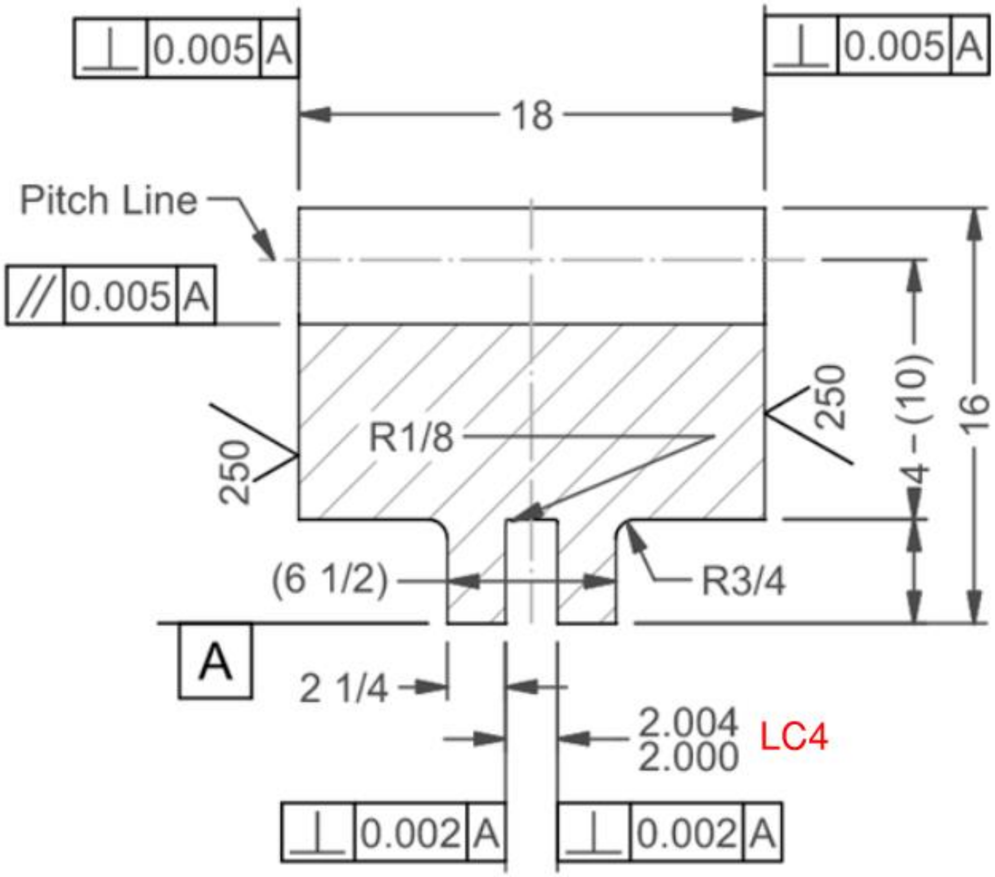


LINK ARM BEARING ASSEMBLIES

The issue with this detail is not only the tight tolerances specified, but the lack of adjustment to achieve the specified tolerances. The bearing housing fits in the bascule girder with an FN2 interference fit and is then further secured with a hub ring and bolts. This results in a very secure assembly that cannot be adjusted relative to the girder or disassembled from the girder. Therefore, the only means of adjustment is to adjust the position of the bascule girder which is not practical to the specified tolerance. In addition, movement of the rack girder could affect the trunnion alignment as one of the trunnions is also mounted in the bascule girder.

Rack Mounting Detail

A section from the shop drawings through the span drive machinery rack is shown below. The LC4 fit was originally shown as an LC1 fit. An LC1 fit provides for 0.0000" to 0.0012" clearance, based on a slot tolerance of 0.0007" and a mating part tolerance of 0.0005". The manufacturers we spoke with said that the LC 1 fit could not be achieved with the part details shown on the drawings. During construction the engineer agreed to change the tolerance to LC4. This change provided nearly 6 times the clearance of the originally specified fit and made it possible to manufacture the part.



SECTION A-A

The three examples provided above were questioned in the bid phase of the project. For the most part questions related to alignment and tolerances were not changed prior to the bid. As a result, contractors were left not knowing how the owner and the engineer would enforce requirements that were impossible to achieve.

The contractor made significant efforts to achieve the specified tolerances including detailed installation procedures, using a laser tacker to measure alignment, and using custom tapered shims in some instances to achieve the best possible alignment. Despite these efforts, the tolerances provided on the contract were too tight and were ultimately relaxed.

Conclusions

Tolerances and hold points are essential in movable bridge construction. They provide meaningful information for manufacturing, construction and inspection. There is generally more guidance in the applicable manuals and specifications on tolerances than there is on hold points. Guidance on tolerances is limited to tolerances associated with fits and finishes of parts. Global positioning tolerances and tolerances for alignment of parts are generally not available, leaving the engineer to decide what is acceptable based on induvial experience. Hold points are not addressed by either AREMA or AASHTO and are for the most part not specified in contract documents for movable bridge construction. The lack of information available to the industry can lead to confusion, disagreements, project delays and cost overruns as demonstrated by the case studies cited in this paper. This is not good for the engineer, owner, contractor or our industry in general.

There is a need for our industry to develop practical, achievable and measurable tolerances and hold points that are common to movable bridge construction projects. Hold points need to be enforced and owners need to provide timely and effective inspection of completed work so as not to delay construction activities. Some work is being done in this area, but the outcome of the effort will not be known for some time. In the interim it will remain up to the engineer and the owner to develop contract documents that are in the best interest of all stakeholders. The contract documents should include achievable tolerances and alignment criteria as well as explicit hold points at critical stages of construction. Timely inspections and review of contractor supplied inspection data are crucial to avoiding delays in construction. It is essential that time requirements for hold points be established in the contract documents and adhered to throughout construction.