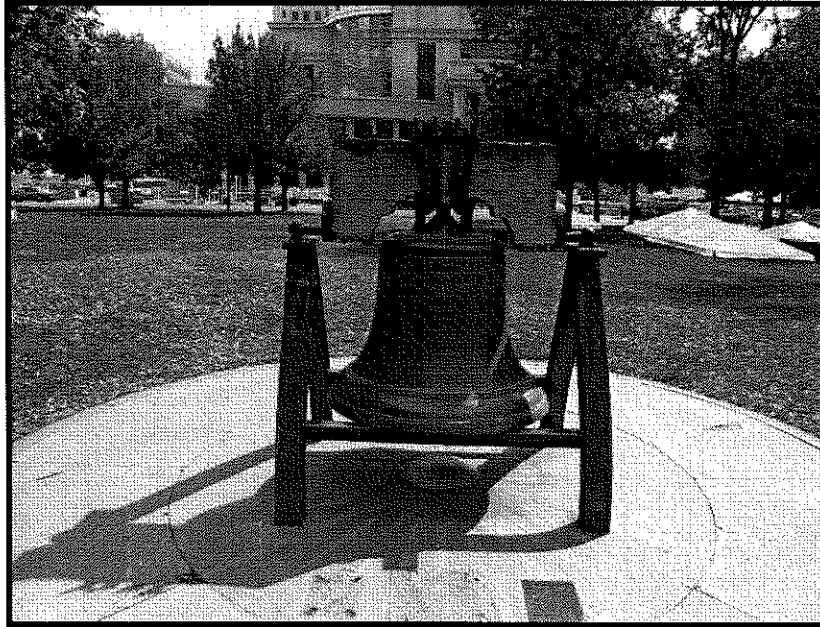


*Proposal:*

**Investigation of Liberty Bell Replica,  
Denver, Colorado**



*Submitted by:*

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October 15, 2012

*Proposal:*

## **Investigation of Liberty Bell Replica, Denver, Colorado**

### **BACKGROUND**

Anthony & Associates, Inc. (A&A) was contacted by Ms. Sue Johnson of the Mount Rosa Chapter of the Daughters of the American Revolution (DAR) about the condition of the Liberty Bell Replica in Lincoln Park, Denver, Colorado (the Bell). After conducting a brief site visit to the Bell, A&A was asked to submit a proposal for conducting an investigation and providing preservation options for the Liberty Bell Replica.

Several professionals have previously examined the Bell but have come to different conclusions regarding the condition and proper preservative treatments to ensure that the Bell remains as a historic fixture in Lincoln Park for decades to come. In order to determine suitable repairs and preservation options for the Bell, it is necessary to first understand how the Bell is supported and whether the current support system has deteriorated and is no longer adequate. That is the purpose of this investigation.

### **SCOPE OF WORK**

The focus of this work is on understanding the structural support of the Bell. The wood and steel components support the Bell but are showing signs of weathering and distress. It is not known whether the current support system can adequately support the Bell over time, particularly if the intent is to be able to ring the Bell on historic occasions.

The scope of work includes:

- Inspecting the Bell for wood or metal deterioration.
- Identifying the wood species of the wood yoke.
- Conducting a structural analysis of the Liberty Bell Replica support frame.
- Providing preservation options for ensuring the structural integrity of the Bell.

### *Wood and Liberty Bell Investigation*

Anthony & Associates will assess the condition of the wooden yoke to determine wood species, assess the presence of any defects or deterioration that might affect the long-term performance of the Bell, and provide material input for the structural analysis.

A very small wood sample will be removed to identify wood species. Identifying wood species makes it possible to determine material properties for conducting a structural analysis and to identify compatible material for repairs. Visual inspection, probing and, possibly, resistance drilling will be used to determine the presence and extent of wood deterioration. Visual inspection enables detection of external wood decay fungi or insect activity as determined by the presence of decay fruiting bodies, fungal growth, insect bore holes or wood substance removed by wood-destroying insects. Resistance drilling is a quasi-nondestructive technique for determining the relative density of wood. It is best suited for determining internal problems in timber, like the yoke, that does not show obvious signs of deterioration, such as surface decay. Any internal void or early stage of decay at the location drilled can be detected by determining the relative density of the wood. The relative density is printed on a strip of paper as a small diameter needle penetrates the wood.

Anthony & Associates will also assist the DAR in obtaining information on other Liberty Bell Replicas and how they have been restored and maintained. The project team has worked with firms that have assessed other bell replicas and will incorporate those findings into the recommendations for the preservation of the Bell.

### *Structural Analysis*

Atkinson-Noland & Associate (ANA) will conduct a site visit to the Liberty Bell replica in Denver to obtain detailed measurements of the bell support structure. Included will be the dimensions of all external steel elements, determination of the thickness of the steel strap embedded in the wooden yoke using an ultrasonic thickness gage and scanning of the remaining wood surfaces with microwave radar to determine if there are other embedded metallic elements in the wood. We assume that an accurate weight of the bell is available.

Based on the measurements, we will develop a finite element model of the bell support structure to determine the stresses and deflections of the support structure under static and dynamic (ringing) conditions. Finite element analysis

(FEA) is a frequently used engineering technique for calculating and visualizing the stress distribution and deformations in complex structures. As an example, ANA recently used finite element analysis to evaluate an elliptical masonry arch at the historic Norlin House in Boulder. The FEA model (Figure 1) indicates very little compression in the relatively flat arch when subjected to dead, live and snow loads. The model confirms the diagnosis that the arch geometry is too flat for the span and loads and explains why the voussoir stones have slipped near the crown of the arch. Retrofit options were evaluated using the FEA model and post-tensioning the arch with an internal steel tendon was determined to dramatically improve the load capacity of the arch (Figure 2).

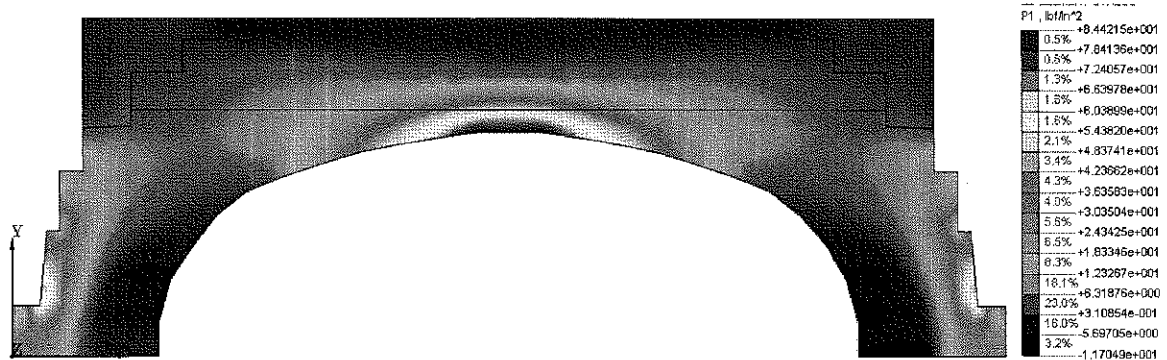


Figure 1. Finite element model of stone masonry arch subjected to dead, live and snow loads. Red shading indicates zone with low compressive stress.

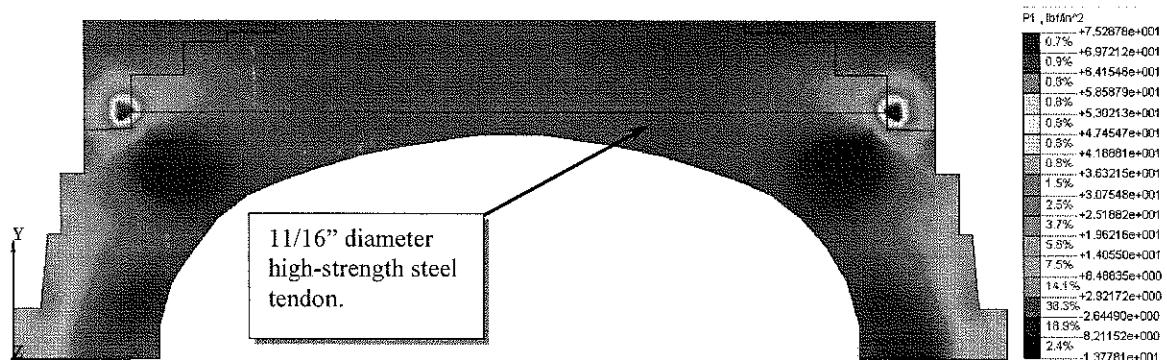


Figure 2. FEA model with post-tensioned tendon placed in cored hole within arch. Full arch is in compression.

Similar to the arch analysis, the model of the Liberty Bell replica will indicate where stresses are high in the steel and timber support structure and, if necessary, we can use the model to evaluate strengthening measures or alternate support conditions to eliminate overstress conditions.

## DELIVERABLES

The deliverables will be a project report that will include:

- A discussion of the field and data analysis methodology.
- Identification of the wood species or wood species group of the yoke.
- Opinions on the general condition of the structural support system based on visual inspection, wood inspection, and structural analysis. This will help to determine if the Bell support system is (a) generally unfit to remain in service as is for decades, (b) deteriorated or in need of selected repair or replacement or (c) generally in sound condition and suitable for continued use.
- Provide preservation options, including conceptual retrofit options.

It should be noted that, based on the need to assess the Liberty Bell Replica, the National Park Service - National Center for Preservation Technology and Training (NCPTT) has tentatively agreed to fund research to conduct digital radioscopy of the Liberty Bell replica. The use of low-energy portable x-ray technology would allow for us to better understand the deformed shape of the supporting frame under the weight of the bell. This information has not been collected on any other replica and would be useful not only to the proposed investigation but the analysis and preservation of other Liberty Bell replicas.

NCPTT has agreed to provide funds to support Anthony & Associates in conducting the digital radioscopy, provided that NCPTT has access to the results of the radioscopy work. Anthony & Associates developed the use of digital radioscopy for assessing historic structures approximately a decade ago with financial support from NCPTT. **There would be no cost to the DAR for this phase of the work.**

## BUDGET

Mr. Ron Anthony, Wood Scientist for Anthony & Associates, will serve as the project lead. Mr. Dave Woodham, P.E. at Atkinson-Noland & Associates will coordinate the structural analysis phase of the work.

**The cost for conducting the investigation, data analysis and report writing is \$9,850.** An invoice for the work will be submitted with the report. Payment is due upon receipt of the report and invoice.