**St. Paul's Liberty Lutheran Church**
**Cemetery Association**

3494 Oak Park Road
Deerfield, WI 53531

February 12, 2019

Dear Zoning and Land Regulation Committee Members:

This letter is in response to the document that was submitted by the Oak Park Quarry pertaining to the renewal application of CUP 02449. The document was written by Dr. Lawrence Gubbe nearly three years ago, as it addresses the issues that were presented and discussed at the Town of Deerfield Public Hearing on March 29, 2016. The attorney for the quarry, i.e., Mitchell Olson, sent the document to the Town of Deerfield and the ZLR Committee on April 5, 2016.

Since I have been serving as the technical consultant for St. Paul's Liberty Lutheran Church, the church submitted my rebuttal to Dr. Gubbe's comments to the Deerfield Town Board and the ZLR Committee on May 10, 2016.

As a matter of record, I would like to resubmit this rebuttal to the ZLR Committee. The original document that I wrote in April of 2016 is attached.

Thank you.

Sincerely,

Roxann L. Engelstad

Dr. Roxann L. Engelstad
Secretary of the Cemetery Association

# Rebuttal to Dr. Gubbe's

## *"Comments on the Public Hearing on Blasting at the Oak Park Quarry"*

Dr. Roxann L. Engelstad

*April 2016*

### I. Introduction

***Dr. Gubbe states that I am lacking in "training, experience or expertise in structural engineering …"***

In 1988, I received my Ph.D. in Engineering Mechanics with a minor in Civil Engineering (specifically in structural dynamics) from the UW-Madison. My dissertation was on the nonlinear vibratory response of structural components in nuclear fusion reactors caused by sequential blast loadings. After completing my degree, I joined the faculty in the UW College of Engineering, and served as Chair of the Mechanical Engineering Department from 2007 to 2013. I spent my early career researching the design of containment vessels and first wall protection schemes for inertial confinement fusion reactor chambers. This involved determining the dynamic structural response of cylindrical and spherical vessels (and their components) due to nuclear implosions. This work was primarily funded by Sandia National Laboratory and the Karlsruhe Nuclear Research Center (Germany). My most recent research has dealt with mechanical issues in the area of nanolithography and the development of the next generation of computer chips for the semiconductor industry. I have authored/co-authored 121 archival journal publications and 157 conference proceedings, given over 75 invited presentations (nationally and internationally), and advised 17 Postdocs, 21 Ph.D. students and 30 M.S. students. Instructional duties include teaching undergraduate and graduate courses in the areas of dynamics, structural analysis, vibrations, and solid mechanics. As a result of my research and teaching accomplishments, I currently hold two Chaired Professorships, i.e., the Timoshenko Chair and the Weideman Chair of Mechanical Engineering. In addition, I was named a Fellow of the International Society for Optical Engineering in 2003 and a Fellow of the American Society of Mechanical Engineers in 2014.

### II. Reference Standards Cited by Dr. Engelstad

***Dr. Gubbe discredits the publications and standards that were cited in my presentation because they deal with transportation and construction induced vibrations.***

On Slide #3 of my presentation, I showed the blasting level graph (of PPV vs. frequency) from the U.S. Bureau of Mines report USBM RI-8507, which is now a part of the Wisconsin State Code on blasting limits. This graph is **not** applicable to historic, stone-masonry structures.

As indicated on Slide #9, there is no commonly accepted standard for the vibration limits to protect historic structures. A few states have adopted their own standards for historic buildings, however Wisconsin has not. In my presentation, I noted that the National Cooperative Highway Research Program (NCHRP) published a survey report in 2012, which gave a comprehensive summary of 20 references that provide vibration limits for historic structures. As stated in this survey, the goal of the report was "to help historic

preservation resource agencies and organizations, departments of transportation (DOTs), and the public understand the technical aspects of vibration impact studies." In essence, the various references cited in the NCHRP report each recommend guidelines on the necessary vibration limits to protect historic structures from construction-related vibrations. It is a challenge to find significant studies or compiled data that deal with vibration generated by blasting only in the vicinity of historic structures (and the reasons are rather obvious).

Consequently, since construction-related vibrations cover both continuous sources of vibration (e.g., pile driving, vibratory compaction, etc.) and transient sources of vibration (e.g., blasting, sudden ground impacts, etc.), it is reasonable to review the literature in this area. A number of the references actually provide separate guidelines for PPV limits on the two sources of vibration, as a function of the type of structure and its condition.

**(a) Wiffin and Leonard**

***Dr. Gubbe writes, "This is clearly an inappropriate and misleading reference to apply to vibration generated by blasting which are transient, short duration vibrations that occur a handful of times a year.***

It was made clear on Slide #11 that this reference provided an assessment of the type of damage that can be expected from a continuous vibration source – there was no intent to mislead the audience. However, what is misleading is Dr. Gubbe's statement about the blasting in the quarry occurring "handful of times a year." In 2015, there were 31 blasts over 4.5 months (from July 21$^{st}$ to Dec. 4$^{th}$), which could easily double to 62 if you consider blasting over 9 months during the year. This is definitely more than a "handful."

**(b) FTA**

It was made clear on Slide #12 that the Federal Transit Administrative guidelines were for construction vibrations.

**(c) CALTRANS**

***Dr. Gubbe is concerned about applying the CALTRANS guidelines to historic structures, particularly the use of Table 19 from the CALTRANS manual. He states that the recommendations in Table 19 "are applicable only to transient vibration generated by construction equipment, as clearly stated in CALTRANS (2004), not to transient vibration generated by blasting."***

I am not in agreement with Dr. Gubbe's statement. For example, below is a copy of Table 19 from the CALTRANS manual. The note beneath the table provides the definition of transient vibration sources and continuous vibration sources to be used with the table. Obviously, **blasting is listed as a source of transient vibrations.**

Table 19. Guideline Vibration Damage Potential Threshold Criteria

| Structure and Condition | Maximum PPV (in/sec) | |
|---|---|---|
| | Transient Sources | Continuous/Frequent Intermittent Sources |
| Extremely fragile historic buildings, ruins, ancient monuments | 0.12 | 0.08 |
| Fragile buildings | 0.2 | 0.1 |
| Historic and some old buildings | 0.5 | 0.25 |
| Older residential structures | 0.5 | 0.3 |
| New residential structures | 1.0 | 0.5 |
| Modern industrial/commercial buildings | 2.0 | 0.5 |

Note: Transient sources create a single isolated vibration event, such as blasting or drop balls. Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.

In addition, if you consider blasting during a construction project, the total number of blasts in a specific location will probably be minimal. If anything, the maximum PPV value given in Table 19 for transient sources is probably too high, since most construction projects are relatively short-term, whereas the CUP for the Oak Park Quarry was for 10 years.

## III. Examples Presented to Support the Proposed Limit on Blasting Vibration

***Dr. Gubbe is concerned that the Case Studies I used to illustrate the use of the guidelines for historic structures were for "…continuous vibration generated by traffic and construction …."***

Again, there are numerous studies and reports available on how to apply the guidelines for the preservation of historic structures exposed to construction-related vibrations. **I found no Case Studies pertaining to the effects of blasting near an historic structure.** Consequently, I chose five examples of structures that had been categorized as fragile and historic – all were to be subjected to vibrations from construction-related vibrations and this was made clear on each of the slides presented. The intent was to provide some guidance on how to establish the blast limits for historic structures in our area.

### (a) Cypress Lawn Cemetery

The two case studies presented in Slides #14 and 15 were chosen because they were both considered to be fragile structures in a cemetery that was located near the BART construction project. Even though the structures were well-maintained and **only 100 to 125 years old**, extra precautions were taken to ensure that construction vibrations would cause no damage, i.e., by lowering the PPV level and even adding temporary interior supports.

### (b) Shiloh Baptist Church

A maximum PPV of 0.12 established for the Shiloh Baptist Church was actually set for *all* construction-related activities. This was primarily due to the fact that this historic church was in a "somewhat fragile condition," even though it was **less than 100 years old**. Using the Swiss Standards, the church fell under the category of Class IV: construction very sensitive to vibration; objects of historic interest. Quoting from the HMMH Project Report:

*"The FTA guidance manual provides construction vibration criteria for potential damage effects as well as vibration criteria for annoyance effects. The vibration damage criteria depend on the building sensitivity category and are taken from a Swiss Standard that has been used on major construction projects in the USA. For the most sensitive building category, which applies to the buildings such as the Shiloh Baptist Church that are extremely susceptible to vibration damage, the recommended criterion is 0.12 in/sec in terms of PPV …."*

It should be noted that the concern about pile driving and the drilled shaft construction (as pointed out by Dr. Gubbe in his set of comments) was primarily due to the annoyance it would cause to building occupants. For these construction-related activities, the HMMH Report recommended the following:

*"Vibration mitigation measures that can be considered to minimize annoyance include scheduling construction work to avoid drilled shaft construction within 90 feet of the building during sensitive activities at the church and by using alternative bridge construction methods to limit impact pile driving within 520 feet from the building."*

**(c) St. Louis, King of France Catholic Church**

***Dr. Gubbe refers to a study completed by the Metropolitan Council in the Minneapolis/St. Paul area in 2008. As he states, "The study considered the potential effect of all rail traffic on the church." He continues on to emphasize the number of times the trains would pass by the church over the next 50 years. And he concludes by stating, "The effects of long-duration vibration occurring 100 times a day, 365 days a year over a period of 50 years are not applicable to the transient vibration generated by quarry blasting that occurs a handful of times a year."***

Unfortunately, it appears as if Dr. Gubbe is drawing his conclusions from a study conducted in 2008, when I was referring to **2010** report that was published by ATS Consulting as a **pre-construction survey** for the Central Corridor Light Rail Project. As it states in the 2010 report, one of the goals of the project was *"minimizing damage caused by vibration during construction."* MacDonald & Mack Architects were hired to conduct a *"detailed review of historic buildings to warrant special consideration in the development of vibration limits and mitigations during construction."* The specific recommendation for the St. Louis, King of France Catholic Church was:

*"In addition to the standard vibration mitigation measures of the pre-construction survey and vibration monitoring, it is recommended that glass shades of the wall sconces be removed or secured prior to the start of construction and that the stained glass windows be visually inspected during construction to verify that no degrading is occurring. The vibration limit for the church is 0.12 PPV in accordance with the FTA criteria for a fragile historic building."*

## IV. Observed Damage to Liberty Church and Appurtenant Structures

### (a) Spalling of the masonry near the ground level

***Dr. Gubbe stated that I showed photographs of the "spalling of the masonry on the exterior of the church at and just above the ground level." He explained this damage by stating, "Damage of this type is typically the most severe near ground level where cyclic freezing and thawing of snow exacerbates the problem."***

Actually, the mortar and stone are not spalling from the base of the bell tower, but rather from the upper portion of the bell tower. It was impossible to get a single photograph of the mortar and stone on the ground, as well as the cracks in the upper portion. Consequently, in my presentation I showed a photograph of the entire church to illustrate the height of the bell tower, with a second photo of the mortar and stone at the base of the bell tower on the south side to illustrate the amount that has fallen.

### (b) Vertical crack near window of church

***Dr. Gubbe has no comment.***

### (c) Separation of joint in drywall in Educational Building

***In the introduction to his report, Dr. Gubbe stated, "Damage to the educational building consisted of separation of a taped joint in the gypsum wallboard ceiling …"***

The photographs of the separation of the joints shown in the presentation were not taped joints. They were joints between the drywall ceiling and the concrete block walls – thus, the joints had been caulked.

### (d) Vertical crack in the concrete masonry wall of the Educational Building

***Dr. Gubbe has no comment.***

### (e) Shifting of tombstones

***In Dr. Gubbe's concluding remarks he states, "by the simple application of the basic laws of physics I showed that the vibration generated by blasting at the Oak Park Quarry could not be responsible for shifting of the tombstones on their bases."***

I have a number of separate comments to make on Dr. Gubbe's analysis of the tombstones:

1.) Dr. Gubbe's first approximation was assuming the ground borne vibration could be represented as simple harmonic motion and he copied the equations for displacement (D), velocity (V), acceleration (A) and frequency (F) from some unspecified reference. (Actually these equations can be easily derived using

elementary kinematic relationships.) Note that, when accelerations of the blasting wave are calculated in this manner (instead of being measured), the result obtained is usually much lower than the actual value, because the vibration wave is not a true sinusoidal function (it is much more complex). In order to get a more accurate evaluation of the accelerations generated from the blasting, accelerometers should be placed directly on the tombstones to measure the magnitudes *in situ*.

2.) Dr. Gubbe's second assumption was that the largest blast at the church had a maximum PPV of 0.41 in/sec with a corresponding frequency of 24 Hz. I do not believe this is true. Unfortunately, the church was not monitored until I requested that a seismograph be placed at the church for every blast – this began on July 21, 2015. However, there was a "misfire" at the quarry on August 12, 2015, and the seismograph at the church did not record the blast (as noted by the State Blasting Inspector). In addition, I was present at the church for nearly all of the blasts from July 21 to Dec 4, and the "misfire" was definitely the worst blast that I encountered (it was felt ~2.5 miles away in two locations to the south and east of the quarry). Furthermore, the blasting that took place before July 21, 2015, was not recorded at the church; however, seismograph data at other locations are available for the beginning of 2015 blasting season, as well as in 2014.

3.) Dr. Gubbe's third assumption was that the maximum horizontal acceleration could be calculated from only one component of the total acceleration. For this case, he chose just the longitudinal component of the velocity, which was 0.41 in/sec at 24 Hz. However, the ground borne vibration wave has components in three orthogonal directions, i.e., longitudinal, transverse and vertical. The horizontal component of the acceleration vector is the vector sum of the longitudinal and transverse components computed at the same point in time. In other words, the two in-plane components must be used to determine the maximum horizontal acceleration. Dr. Gubbe did not do this; consequently, he has underestimated the acceleration by a significant amount.

4.) The fourth and fifth assumptions made by Dr. Gubbe were that when upper portion of a tombstone shifts relative to its base, the contact area is basically granite on granite – and he uses a kinetic coefficient of friction of 0.60 and a static coefficient of friction of 0.75 to 0.80. First of all, measured data of polished granite on polished granite has coefficients of sliding friction that can be as low as 0.3. Secondly, many of the tombstones that have shifted actually have a band of sealant material that is used **between** the surfaces of the upper and lower portions of the stone (this band is usually around the perimeter of the contact area). In other words, we often do not have the case of "granite sliding on granite." Over the years, this sealant can become "hardened or brittle" and thus is relatively weak in shear. When the tombstone undergoes ground vibrations, the seal breaks down allowing the upper portion of the stone to displace relative to the base.

5.) The final point to be made, is that a number of the tombstones are "tilted" due to the ground settling at the grave site (or maybe even due to blasting shifting the ground beneath the cemetery). It is interesting to note the number of stones that have moved "up-hill" relative to their base, i.e., defying gravity.

In conclusion, consider a second back-of-the-envelope calculation (Dr. Gubbe refers to this as high school physics) using seismograph data at a location that experiences comparable blasting effects (both in PPVs and frequencies). On March 16, 2015, a blast wave generated **in-plane accelerations of 0.613g**, and if the vertical component of acceleration is included as well, shifting of the tombstones is certainly possible.