BRIERLEY ASSOCIATES
Creating Space Underground

September 7, 2018

Town of Brookline
Department of Planning and Community Development
333 Washington Street
Brookline, MA 02445-6853

Attention: Alison Steinfeld, Planning Director

Blasting Impacts Assessment
Puddingstone at Chestnut Hill
259 Gerry Street
Brookline, MA

This letter presents the results of our review of the proposed Blast Plan, and assessment of the blasting impacts from construction for the proposed residential building development within Hancock Village. The purpose of our work was to assess the areas on site where drilling and blasting will be required for bedrock excavation, and to assess the potential impacts from the blasting work on nearby residential buildings and people in the area. Bedrock excavation by drill and blast methods will be completed by Maine Drilling and Blasting (MD&B) of Auburn, NH.

Background

We have reviewed the following background information to complete our assessment:

- Zoning Board of Appeals Presentation of the Puddingstone at Chestnut Hill Development by Stantec, March 22, 2018.
- Blasting Plan for Puddingstone at Chestnut Hill by Maine Drilling & Blasting, Inc., dated August 17, 2018.
- NFPA 495 Explosives Materials Code, 2013 Edition.

As part of our evaluation, Mr. Jay Perkins of Brierley Associates has discussed the proposed project development, and abutter concerns with Ms. Alison Steinfeld Town of Brookline Planning Director, and has discussed the submitted Blast Plan with Mr. Ken Smith of MD&B. In addition, Mr. Perkins has completed a site visit on August 13, 2018 with Mr. Ken Smith and Ms. Alison Steinfeld, and discussed the project development.

There are four building sites located on the north side of Sherman Road at the west end of Hancock Village bordering the Hoar Sanctuary to the west. The site is surrounded by occupied 2-story residential buildings, several of which will be demolished to allow for the proposed building construction. Bedrock outcrops extend up to approximately 20’ above the surrounding grades within the proposed development area. Development will consist of a rectangular-shaped 6-story “Apartment N1” building with two levels for below grade parking with a footprint area of approximately 56,000 sf, and three 2-1/2 story “Infill N2, N3 and N4” buildings each with a rectangular footprint area of approximately 4,000 sf. The two levels of parking will extend approximately 20’ below grade.

There is exposed bedrock outcrops and shallow bedrock in the area. Building construction will require up to 37' of above and below grade bedrock excavation by drill and blast methods of Roxbury Conglomerate bedrock, locally known as Puddingstone bedrock. MD&B has estimated bedrock excavation by drill and blast methods of approximately 50,000cy for the N1 building, 1,500cy for the three Infill buildings, and 600cy for buried utilities. The groundwater level was observed in some areas at 5' below grade.

Blast Designs

MD&B has provided three (3) Test Blast designs and four (4) preliminary production blast designs in their submitted Blasting Plan to begin the rock excavation for building construction. Blasting will begin at the west end of the proposed N1 building across from the Hoar Sanctuary next to Sherman Road. Approximately 50,000cy of excavated rock has been estimated for construction of the N1 building with rock cuts up to approximately 20' deep below grade.

Blast designs include drilling a 2.5" and 3" diameter holes to depths of between 6' and 16' at a 3' to 5' burden by 3' to 6' hole-to-hole spacing. The number of holes per blast round will range from 12 to 40 for the test blasts and up to approximately 60 holes for production blasting. For trench excavation, 3" diameter holes will also be drilled to an average depth of 9' at a 7' burden and 4' spacing. Actual geometry of the designs will be modified based on the test blast results and as the work progresses.

Explosives used will be Dyno Nobel Blastex (2" diameter by 16" long) booster sensitive and water resistant packaged emulsion and MD&B's 1966 Emulsion Blend of 80% Emulsion and 20% Ammonium Nitrate both primed with Dyno Nobel Trojan Spartan SR (shock resistant) Cast Booster. Initiation system will be the Dyno Nobel Digishot electronic delay detonators. For the preliminary blast designs, the powder factors will range from 1.1 to 1.3lbs./cy. The maximum charge weight per delay will be between 3 to 14lbs. for the test blasts, and up to approximately 35lbs. for the production blast designs. The explosives may be decked if necessary to reduce the charge weight per delay.

Perimeter control will be provided using either Line Drill or Pre-split methods. Line drilling will include drilling 6" diameter uncharged holes at 12" on-center primarily to create a plane of weakness at the line. Pre-splitting will include drilling 3" diameter, lightly loaded uncoupled charged holes at 12" on-center and 20' to 25' deep. A 3" diameter uncharged hole 10' deep will be drilled between the charged holes. The deeper holes will be charged with a Dyno Nobel 7/8" diameter DynoSplit continuous explosive.

For the proposed blast designs, assuming a 9' deep blast holes will produce approximately 7' rock cuts. Each 9' deep hole will be loaded with a 2.5" or 3" diameter column of explosive 5' up from the bottom, with a detonator and cast booster placed at the bottom of the explosive column. The purpose for the detonator is to delay the detonation of each hole so they are detonated independently, and in specific sequence, to allow proper fragmentation of the rock and minimize vibrations from the blasting. The upper 2' to 3' of each blast hole will be filled with crushed stemming stone to confine the explosives in the hole.

The current blasting duration for rock excavation of the N1 building has been estimated to be approximately 55 working days assuming completing two blast rounds per day between 9AM and 4PM.

Anticipated Blasting Areas and Closest Residences and Other Structures

Rock excavation will be necessary to complete the project, with rock cut depths up to about 20' below existing surrounding grades. The bedrock surface at the proposed blast areas extends up to 20' above grade. The following is our recommended list of the existing buildings and areas of concern to be monitored for air and ground vibrations, and their corresponding distance from the blast:

- Owner Controlled on-site residence: 27' to 110'
- Baker School: 720'
- Beverly Road Residence: 820'
- Harvard Vanguard Medical Associates: 1,200'
- Hoar Sanctuary: 100'

Once an understanding of the vibration impacts has been established, one or two of these locations may be removed from the monitoring program.

Blasting Rock

The primary purpose for blasting is to fracture the bedrock to allow for excavation. The explosives produce energy, and the amount of energy required to fracture the rock must exceed the strength of the rock or exceed the elastic limit of the rock. This energy passes through the rock as seismic waves. When this occurs, the rock fractures, and as energy is used up fracturing the rock and eventually falls to a level less than the strength of the rock, the fracturing stops. The remaining energy passes through the rock as a vibration, deforming it but not fracturing it because it is within the elastic limit. This remaining energy causes the rock particles to vibrate, or move from a rest position. The movement or displacement generates a strain that could exceed the tensile strain of a building material and subsequent damage. The velocity of the particle displacement is measured as the Peak Particle Velocity (PPV) in units of in/sec.

When properly designed and detonated, the rock is fragmented between blast holes but there is very little damage to rock outside the limits of the blast holes. For the proposed blast designs, the energy from the blasts will be directed upward and laterally, with little or no fracturing below the bottom of the blast holes. In addition, depending on a proper blast design and what controls are placed on the loading, and assuming a relatively sound and massive bedrock, the fracturing outside the perimeter blast holes is limited to approximately ¼ times the hole depth. Therefore, for 9' deep blast holes, there would be virtually no damage to rock 3' below the bottom of the hole, and no damage to the rock 3' laterally to the perimeter blast holes.

Site Safety and Mitigation

Given the proximity of the blasting activities to the surrounding residents, site safety is paramount to the successful completion of the project. The following provides a list of site safety measures and security that MD&B has implemented during the blasting:

- *Worker:* Daily Safety Meetings
- *FD:* On Site during every blast.
- *Blast Area Security:* Designated Access Points and Safe Areas, Sentry Locations (see Plan)

- *Charged Hole Area:* Posted, Guarded and Barricaded
- *Warning Signals:* Three (5 minutes), two (1 minute), one (all clear).
- *Sherman Road:* Closed to vehicle and pedestrian traffic.
- *Shot Cast Control (flyrock):* Matting and blast rock berms.
- *Blast Monitoring:* Seismographs to measure PPV and AOP at five (5) locations as per ISEE Guidelines.
- *Misfires:* Wait, reconnect and reshoot, reprime, washout with water or air, recover, displace (drill and shoot adjacent hole), and disposal to separate magazine

Potential Impacts of Blasting on Abutting Residential Buildings

The primary concerns with blasting close to residential buildings and their occupants are ground vibrations and elastic displacements, air blast overpressures, flyrock, noise and dust, all of which can be controlled with experienced Blasters and Consultants applying modern techniques to blasting designs and mitigation measures. The following addresses those concerns, and are included in MD&B Blast Plan:

Ground Vibrations: Ground vibrations are measured in PPV, since standards of damage are based on the ground particle velocity. The PPV from each blast round will be monitored using seismographs set up immediately adjacent to the structures of concern as described above. Blasting will start at the west end of the building site with a series of three (3) smaller "test blasts" so that relationships between charge weight per delay can be adjusted from the initial blast design as needed, and peak particle velocities can be developed prior to getting into production blasting and closer to the buildings.

*Allowable Blast Vibrations at Buildings: G*round vibrations at buildings and any structures will be kept below the safe limits line recommended by the U.S. Bureau of Mines (USBM RI 8507, 1980), Appendix B, which are provided in the Blasting Plan, and are consistent with the NFPA 495 Explosives Materials Code. These limits are based on the frequency and the PPV of the blast vibrations, and are safe limits for preventing cosmetic damage (hairline cracking, or the extension of existing hairline cracks) to residential structures. This standard provides for a 3 to 5 percent probability of architectural damage to residential buildings, and has been used for many years on thousands of projects.

Using industry standards based on the actual distances between the blast area and the nearest residence and the proposed charge weights provided in the Blasting Plan, the PPVs have been estimated in the Blast Plan. For the Owner's residential buildings, the PPV ranged from 0.26 to 1.17 in/sec from the test blasts and between 1.84 and 1.95 in/sec from the preliminary production blasts. The PPV estimates for the nearest private residence and the Baker School range from 0.01 to 0.05 in/sec from both the test blasts and production blasts. The estimated PPVs all fall below the USBM safe limit line.

Elastic Displacements: The USBM safe limits line, as described above, between 10 and 40 Hz has a constant displacement of 0.008". To give perspective, this is equivalent to the thickness of a standard piece of paper. This is the elastic ground displacement occurring as the vibration waves travel by. Assuming a frequency of 40 Hz, typical frequency for this type of blasting, the elastic displacement for nearest residences for the project has been estimated to be from 0.001" to 0.007", all below the USBM safe limit.

Given each blast causes an elastic displacement of the rock, which implies the rock returns to its original state as the seismic wave passes, there are no accumulative effects from the number or frequency of blast rounds per day. The current Blasting Plan has provided a schedule that proposes two blast rounds per day, which results in completing the blasting activities in 55 working days for the N1 building.

Impacts on People: People can perceive vibrations from blasting at significantly lower levels than might cause cosmetic damage to buildings. Transient vibrations, such as from blasting, may be noticeable, and therefore may result in complaints at peak particle velocities as low as 0.02 to 0.06 in/sec. This is equivalent to the vibrations generated from a heavy truck traveling down a bumpy road. Those vibrations may be disturbing to people, especially if accompanied by noise from air blast, at peak particle velocities as low as 0.2 to 0.4 in/sec. Therefore, residents in the area may feel vibrations, and be disturbed by them, even though the vibration levels are well below safe limit cosmetic damage levels. When disturbed by the blast vibrations, people often inspect their homes for signs of damage, and may find pre-existing cracks which they had not noticed previously. These cracks may then be judged by the homeowner to have been caused by the blast vibrations, and a damage claim could result.

To help prevent or mitigate this type of claim, preblast condition surveys of homes in the area of the project are proposed in the Blast Plan. These surveys would be performed at the interior and exterior of all homes to a radial distance of 300' from the closest blasting, which is also the distance required by the NFPA 495 Code. They have also proposed additional surveys be completed upon request on buildings within 500' of the blast area.

Air Blast Overpressures at Adjacent Residences: Blasting air overpressure, in units of pounds per square inch, (psi) are measured on a Linear Peak scale, and are typically converted and reported as the sound equivalent in decibels (dBL). Air blasts produces an atmospheric pressure wave transmitted from the blast outward into the surrounding area. This pressure wave consists of audible sound that can be heard, and concussion or sub-audible sound (<20 Hz) that cannot be heard. In general, the noise from a blast is felt by the pressure more than heard by the noise. The measurements taken from the recording of the blast round are the air blast overpressure level converted to a dBL scale. If ground vibrations are kept below recommended safe limits, it is our experience that air blast overpressures from blasting are not a threat to damage adjacent structures. However, air blast can cause annoyance, especially in conjunction with ground vibrations.

Using a site K factor of 0.1, and a site attenuation rate of -1.1 (average for confined construction blasting), the air blast overpressures have been estimated for the nearest buildings listed herein and range from 109 to 121 dBL. Air blast at the nearby residences have all been kept below a limit of 133 dB, or 0.013 psi, which is the limit recommended by the U.S. Bureau of Mines to prevent damage to windows. This would be the first damage if it were to occur. Actual breakage of glass would not be expected until air blast overpressures reached 140 dB or higher, much higher than the USBM 133 dB safe limit. Damage to walls of a house would not be expected until air blast overpressures were in excess of 175 dB.

Flyrock: In general, flyrock results from either the face of the blast or the top of the blast, both of which can be controlled by the proper blast design. To reduce the potential for flyrock, the Blasting Plan has provided the following additional controls:

- Placement of blast mats to fully cover the blast area for every blast.
- Construction of blast rock berms between the blast area and the abutting residences.
- Driller's logs will be kept for all blast holes drilled documenting open joints, seams, and other anomalies; and the logs will be reviewed by the Blaster prior to each blast.
- Observation of each blast round detonated so that small problems can be detected and corrected before they become big problems.

Noise and Dust: Noise (high frequency) measurements are typically given as dB as measured on the A scale, different from the Linear Peak scale for measuring air blast overpressure. As a part of the blasting activities, drilling the blasting holes with a rock drill machine (air track), and using a hydraulic hammer to reduce the size of the blasted rock fragments and trim the blasted rock surface can produce excessive noise levels. Our experience has shown that both these activities can produce noise levels in the order of 100 dB as recorded at 5' from the rock drill machine or hydraulic hammer. Normal conversation is approximately 60 dB, and the Town noise ordinance level is 90 dBA (Article 8.15) for construction measured at 50'. As a general rule, noise levels attenuate at a rate of 8 dB to 9 dB for every two times the distance from the source. Therefore, if 100 dB is recorded at 5' from the source, at 10' the noise level would be approximately 92 dB. Based on this attenuation rate, the noise levels from the drilling and hammering should be below the typical ordinance level. As indicated in the Blast Plan, noise levels will also be reduced with appropriate barriers and mufflers.

Dust produced from the drilling and blasting activities will be controlled by the use of water or other fluid placed at its source and drill machines equipped with dust collectors as indicated in the Blasting Plan. In addition, we recommend dust monitor placement around the site perimeter in the area of the residences, to ensure that dust levels off site remain at safe levels.

Conclusions

In summary, it is our opinion that proposed Blasting Plan submitted by MD&B for rock excavation at the site provides the majority of controls and mitigation measures to levels which should not adversely impact residential structures in the area. The primary concerns that have been discussed include site safety and security, ground vibrations, elastic displacements, air blast overpressures, annoyance to residents, flyrock, noise, and dust. The following provides a brief summary of the assessment:

- A detailed Site Safety and Security Plan has been provided in the Blast Plan.
- Blasting will start with smaller test blasts at the west end of the site development area.
- Rock fracturing from the blasts (plastic zone) is limited to not more than 3' below the bottom and 3' laterally from the blast hole.
- Blast induced ground vibrations, as recorded at the nearest building and buildings of concern will be kept below the USBM recommended safe limits. The estimated PPVs range from 0.26 to 1.17 in/sec from the test blasts and 1.84 to 1.95 in/sec from the production blasts as measured at the Owner's residential buildings. The estimated ground vibration levels have been estimated to be much less for the private residential buildings.
- Elastic displacements calculated at the nearest buildings are below the USBM safe limits and have been estimated to be between 0.001" and 0.007".

- Elastic displacements are not cumulative and therefore the number of blast rounds per day will not be a concern. An additional blast crew should be considered in an effort to decrease the blasting duration to less than the currently scheduled of 55 working days for the main building.
- Blast rounds have been designed to maintain air blast overpressures below 133 dBL safe limit as per USBM standard. The estimated air blast overpressures for the nearest buildings listed range from 109 to 121 dB. Added mitigation to air overpressures will be provided by the placement of rock fill berms between the blast area and the residential buildings. This will minimize the possibility of any window damage and annoyance due to rattling of windows.
- Residents in the area may feel vibrations, and be disturbed by them, even though the vibrations are below the safe limit cosmetic damage levels.
- To minimize potential damage claims, as per the Blasting Plan, pre-blast condition surveys will be conducted of the interior/exterior of all buildings within a 300' radius of the blast areas, and within 500' upon request.
- Flyrock will be controlled as per the Blasting Plan by proper blast designs, placement of blast mats, placement of rock fill berms, review of driller's logs and observation of each blast round.
- Dust generated from drilling and blasting will be controlled by placement of water in the blast area, and drill machines equipped with dust collectors.
- Noise from a blast is typically felt by the overpressure more than heard by the noise.
- Audible noise generated by rock drill machines and hydraulic hammers should attenuate at nearest buildings to levels below the Town ordinance.

Recommendations

The following provides our list of recommendations to be implemented during the blasting phase of the project:

- Understanding of groundwater, and groundwater control during blasting.
- Post blast rock wall stability evaluation by the Project Geotechnical Engineer.
- Project Geotechnical Engineer to provide recommendations for temporary wall support, if needed.
- Blasting Consultant present on site during test blasts.
- Blaster's post blast reports including seismograph event report sent to Blasting Consultant for review within 24 hours of blast.
- Submit updated regression analysis to Blasting Consultant for review.
- Submit any revised blast designs to Blasting Consultant for review.
- Monitor noise and dust.

Frequently Asked Questions

What is the volume of rock that blasting will remove and how long will it take?

MD&B has estimated a total 50,000 cy of rock will be excavated for the N1 building for a duration of 55 working days. This assumes one crew completing two blast rounds per day. Blast rounds per day can be increased without any potential concerns for building damage.

How long will it take for the drilling the blast holes and what are the noise levels from the drilling and rock drill machine (air track)?
Blast hole drilling will be completed with a pneumatic percussive drill machine (air track) and air compressor. MD&B has estimated an average of 50 3" diameter by 9' deep blast holes per blast round at two blast rounds per day. This results in 1,080' of drilling per day. Average air track production will be approximately 500 feet per day for one machine. Two machines will be needed to drill the blast holes for completing two blast rounds per day. Noise levels from both the air discharge and steel drill rods can be as high as 110 dB at the operators' ears and 100 dBs at 5' from the source. At the nearest residence, we can expect noise to attenuate to levels below the Tow ordinance level of 80 dB for construction with the placement of the rock fill berms and noise barriers.

Size of Blast? Series of smaller shots or fewer larger shots?
This question gets into the means and methods of the Licensed Blaster, who is responsible for safety at the site, and needs to be allowed to use methods that he is comfortable with, that ensure that the operations are safely performed, and that vibration and overpressure levels at the nearest buildings are within the Safe Limits described herein.

Narrative of what to be done in blasting process.
Details of this process are provided in the submitted Blasting Plan. MD&B, who is responsible for safety at the site, has developed the Blast Plan for rock excavation by drill and blast methods based on their experience and expertise.

One of the first steps in the blasting process will be conducting pre-blast condition surveys of nearby residences. For this project, all homes within 300 feet of the blasting areas will be offered surveys.

MD&B has submitted a Blasting Plan indicating the details of his blasting procedures (i.e. hole depths, spacing, loading, estimated vibrations at closest structures, etc.). He will set out signs in the area warning of upcoming blasting. After clearing and grubbing has been completed over the limits of work, any overburden soils will be removed and access to the blast areas, MD&B will start drilling blast holes. This work will start at the west end of the development. MD&B has planned to start with two drill rigs. The drill rigs will be required to have mufflers and dust collectors to reduce noise and dust from the drilling process.

After drilling, the initial test blasting will start. An initial blasts will be done, starting with small charge weights and working up to production level charge weights, in order to assess the vibration attenuation relationships at the site. Prior to each blast, the Blaster in Charge will close Sherman Road, and send out sentries around the site to ensure that no personnel enter the "Safe Area" during the blast. These sentries will be posted at all areas where people could enter the Safe Area, and will be in communication with the Blaster in Charge, so that an "all clear" can be provided before the blast is detonated. The Blaster in Charge will then blow a warning horn 3 times at five minutes and two times one minute prior to detonation. Following the blast, the Blaster in Charge will sound the horn once for the "all clear" signal, provided no misfires have occurred.

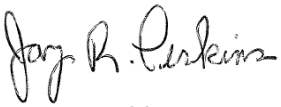
Seismographs will be utilized during the blasting program, and set up at the closest residence, in order to develop Scaled Distance relationships (relationship between charge weight per delay, distance, and peak particle velocity of ground vibration) at the site. MD&B will then continue to

drill, load, and detonate blast rounds to develop the excavation in a general west to east direction. During blasting at the site, vibration monitoring will continue at the closest residences.

Blasting mats will be utilized for each blast in order to reduce the potential for the throw of flyrock from the site. As rock blasting continues, the fragmented rock will be dug with a large excavator and placed along the north side of the blast area between the abutting residential buildings creating a rock berm for added protection and air blast pressure mitigation. All remaining rock will be loaded into trucks for offsite disposal. A traffic plan will be developed by the General Contractor to minimize impacts of truck traffic on residents in the area.

We hope that the above comments have addressed any concerns regarding the proposed methods for bedrock removal at the Puddingstone Development at Chestnut Hill project. If you have any questions about our assessment, or require additional information, please feel free to contact me.

Sincerely yours,
BRIERLEY ASSOCIATES



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