INTRODUCTION

Every day construction workers utilize jackhammers to break concrete, asphalt, and various other hard surfaces. The jackhammer operator faces several risks for injury, including exposure to vibration. Prolonged vibration exposure to the hand and forearm can cause hand arm vibration syndrome (HAVS) [1], leading to potentially disabling numbness, tingling, and pain.

Previous studies investigated the relationship between the application of force and transmitted vibration [2]. When the grip forces exerted on the tool handle increase, the transmission of vibration into the hand from the tool also increases [3]. Research by Pyykkoö et al. [4] identified grip force, frequency and magnitude of handle vibration as important factors with respect to the vibration transmitted to the hand, and consequently in the development of HAVS. It was found that if grip strength increases then the vibration also increases with the cube root of the grip pressure [4]. Tool manufacturers have recently developed lighter weight jackhammer designs intended to reduce the required grip and push forces during operation. However, the effect of the new jackhammer designs on grip pressure and the resulting vibrations are currently unknown.

Therefore, the objectives of this study were to compare the measured vibration and grip pressure
1) between conventional (90 lb) and light weight (60 lb) jackhammers; 2) between different pavement type/thickness combinations; and 3) between pneumatic and hydraulic (60 lb & 90 lb) jackhammers.

METHODS

Design-The experimental design included the “breaking” of a 3’x3’ square of four different pavement type/thickness combinations: 4” and 6” thick asphalt and concrete. Five commercially available jackhammers were tested: 1-60 lb hydraulic, 1-90 lb hydraulic, 2-60 lb pneumatic and 1-90 lb pneumatic. Four subjects consented to participate in this study, which was approved by the UWM IRB. Each subject was asked to “break” each pavement type using each jackhammer.

Equipment-An accelerometer was attached to the jackhammer handle (NexGen Ergonomics, sampling frequency 2500 Hz) while another accelerometer (Delsys TRIGNO wireless, sampling frequency 296 Hz) was attached at the subject’s left hand. A pressure-sensing glove (Vista Medical, FSA Glove, sampling frequency 5 Hz), comprised of 24 individual sensors, collected hand grip pressure for the subject’s right hand.

Analysis-The vibration data was analyzed using the VATS software (NexGen Ergonomics Inc, Pointe Claire, Quebec, Canada) using the ISO 5349 standard for hand arm vibration. The vibration data for the jackhammer handle was smoothed by a moving window RMS technique. The data was filtered using a 2nd order Butterworth filter with a low band cut off frequency of 4 Hz using Hanning window size of 1024 data values. A Fast Fourier Transform was performed and 1/3 octave band analysis was conducted. The ISO 5349 weighting factor was applied in each principal axis and the resultant is a single aRMS (aRMS\text{JH}) value. Similarly, the aRMS was calculated for hand vibration (aRMS\text{wrist}). The difference in vibration (ΔRMS) was calculated using:

\[ Δ\text{RMS} = a\text{RMS}_\text{JH} − a\text{RMS}_\text{wrist} \]

A customized Matlab™ algorithm was used to analyze the grip pressure results. For each of the 24 sensors a RMS value was computed and those values were summed to obtain total grip pressure in psi during the trial.

The ΔRMS and grip pressure (psi) were compared across the 60lb and 90lb jackhammers, and the four pavement type/thickness combinations. Pearson correlation was calculated for vibration at the
handle to the grip pressure measured between the pneumatic and hydraulic jackhammers.

RESULTS AND DISCUSSION

Jackhammer Weight – The average hand grip pressure for 60 lb and 90 lb jackhammers was 50.6 and 58.1 psi respectively for subject 4 (Figure 1). The differences in vibration between the jackhammer handle and the hand were 4.4 m/s² and 4.2 m/s² for the 60 and 90 lb jackhammers respectively, also for Subject 4. Similar results were obtained for the other subjects. The 90 lb jackhammers required higher grip pressure during operation, leading to smaller differences between the handle and hand vibrations. That is, higher grip pressure leads to greater transmission of vibration into the hand, as was found in similar research on chain saws [5].

Figure 1: Comparison of hand grip pressure and difference in vibration (ΔRMS) between jackhammer weights for Subject 4.

Pavement Type/Thickness – Grip pressure increased with pavement thickness and was higher for asphalt pavements than for concrete for Subject 4 (Figure 2). Conversely, the vibration difference between the handle and the hand decreases with increasing thickness and is greater for concrete than for asphalt. Similar results were obtained for the other subjects. Overall, the grip pressure and vibration transmission variation is greater across the pavement types/thicknesses than between the different jackhammer weights.

Power Source – Grip pressure averaged 52.7 psi for hydraulic jackhammers and 51.4 psi for pneumatic jackhammers. Similarly, the ΔRMS for the hydraulic and pneumatic jackhammers was found to be 4.5 and 3.5 m/s² respectively.

The Pearson correlation coefficient between grip pressure and handle vibration was 0.39 for pneumatic powered jackhammers and -0.56 for hydraulic powered jackhammers. The correlation of 0.39 indicate a medium correlation between grip pressure and vibration data for pneumatic jackhammers, whereas the -0.56 indicates a stronger negative correlation and negative interaction effect between grip pressure and vibration data for hydraulic jackhammers.

Figure 2: Comparison of hand grip pressure and difference in vibration (ΔRMS) across the difference pavement-thickness types for Subject 4.

CONCLUSIONS

The results of this study indicate that differences in both grip strength and vibration transmission to the hand are affected by jackhammer weight and type. The increase in vibration transmission with increasing grip strength is in agreement with previous studies. Further, the pavement type/thickness had a greater effect on both grip strength and vibration transmission than did the jackhammer characteristics. Further investigation is required to determine the potential benefits of 60lb and 90lb jackhammer including additional factors such as job completion time and muscle activity.

REFERENCES