Development of a Correlation Model between a 20-kg Clegg Hammer and Field CBR for Measuring Subgrade Strength in Forest Roads in Western Oregon

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Abstract

Much of the forest industry in the western United States does not require control of compaction on forest road subgrades despite the potential economic and environmental gains from improved subgrade construction. Development of tools such as the Clegg impact hammer allow for rapid testing of the subgrade during construction, and Clegg Impact Values (CIV) have been correlated with more robust soil test values such as the California Bearing Ratio (CBR) that are often used for road design. A new correlative model that relates the CBR to 20 kg CIV was developed entirely from field data, differing from previously developed models that used laboratory-prepared soils. Another advantage of this model is that it uses a 20-kg Clegg impact hammer. The 20-kg Clegg impact hammer has a larger testing area than the more common 4.5-kg Clegg impact hammer; thus, there is less influence from small deviations in the soil matrix due to items in the fill such as rocks or organic matter. The correlation coefficient for this model is 0.71, which is lower than that for models previously developed from laboratory results. The use of a lower bound, one-tailed, 90% confidence limit is presented as a useful design model to determine a conservative of soil strength that can be measured directly during construction.

Keywords: forest road, subgrade, California Bearing Ratio, Clegg Hammer.

Introduction

Compaction of forest road subgrades receives limited attention in the forest industry. It appears that many companies believe that site-specific soil testing, development of compaction specifications based on that testing, and monitoring of compaction during construction are costs that do not result in commensurate benefits. Additionally, in the western United States, there are no regulatory requirements for compaction of subgrades. Neither California, Oregon, nor Washington forest practices regulations have compaction requirements for forest roads. Often, construction of subgrades is left to contractors' experience to determine when a sufficient bearing strength has been achieved using untested rules of thumb. The result is that compaction may not be done at all, and when done, it is unlikely to be controlled in a manner that is consistent with achieving optimal result. The byproduct of a lack of compaction control is a high degree of variability in forest road subgrade density, with local values along a road often well below those obtained from standard compaction tests (Boston et al. 2008). The weak road subgrades have the potential to increase construction and maintenance costs as well as increase environmental degradation by increasing the sedimentation from forest roads. Boston et al. (2008) presented an analysis that showed that aggregate thickness can be significantly reduced when subgrades are well-compacted.

The environmental damage can increase due to poorly constructed roads. Dawson (1999) compared rut formation on four aggregate types with two subgrade materials. One subgrade was a resilient material (rubber on concrete) and one

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International Journal of Forest Engineering
Volume 21, No. 1

was a soft-clay. Only a weak aggregate material, sand and gravel, showed rutting on the resilient subgrade, while all surfacing types showed rutting on the soft-clay subgrade (Dawson 1999). Thus, even high quality aggregate can be compromised by a weak subgrade, resulting in poor structural performance. These ruts can lead to increased environmental damage. Ruts have been shown to increase sediment production from forest roads, resulting in a reduction in water quality and increasing the environmental harm from forest roads (Foltz and Burroughs 1990). Therefore, there is the potential to reduce road costs and improve the environmental performance of forest roads by improving subgrade compaction.

Achieving the structural performance potential of a forest road subgrade soil requires field verification of compaction during the construction process. While this can be done quickly with a nuclear densometer, the operational overhead of using a nuclear densometer is unattractive due to the array of federal regulations regarding the use, transportation, and storage of nuclear materials. With the development of portable testing devices such as the Clegg impact hammer (Clegg 1976), there is a potential to quickly test the strength of subgrades during construction without any additional soil testing. The Clegg impact hammer measures the peak instantaneous deceleration of a mass dropped from a fixed height as it strikes the subgrade surface. Deceleration of the mass correlates with soil stiffness — the greater the deceleration rate, the greater the stiffness. Stiffness is in turn assumed to correlate with subgrade strength. This technology, when calibrated to subgrade strength as determined by the California Bearing Ratio (CBR), offers a forest engineer the ability to monitor soil strength during subgrade construction to ensure that the desired subgrade properties are being achieved.

The work reported here provides a field-based correlation between the 20-kg Clegg Impact Value (CIV_{20kg}) and the CBR value. The 20-kg Clegg impact hammer was selected because of the averaging ability that it may have over the 4.5-kg Clegg impact hammer due to the larger test area used in the 20-kg hammer. The results from the larger testing surface are less influenced by the discontinuities in the soil matrix such as rocks or organic matter that can occur in non-engineered subgrades used in forest roads.

Previous CBR-CIV Correlations

The Clegg impact hammer was developed in Australia in the 1970s. Recognition of the benefit in having a correlation between the Clegg Impact Value (CIV) and CBR value was realized at the outset. Clegg (1976) proposed the Equation 1 for determining the CBR value of a soil from a CIV for the original 4.5-kg Clegg hammer:

$$CBR = 0.07 \cdot (CIV_{4.5kg})^2 \tag{1}$$

Other empirical equations proposed by Alkire (1987), Mathur and Coghlan (1987), and Al-Amoudi (2002) are shown in Table 1. Mathur and Coghlan (1987) recommended an empirical equation (Eq. 2) of the general form, and recognized that the soil type and local conditions could influence the correlation.

Table 1. Empirical equations relating CBR to Clegg Impact Value [CIV] for the 4.5-kg Clegg.

Reference	Equation	(R^2)[a]	SEE[b]
Clegg (1976)	$CBR = 0.07 (CIV_{4.5kg})^2$	0.79	NA[c]
Alkire (1987)	$CBR = 0.224 CIV_{4.5kg})^{1.67}$	0.94	NA
Mathur and Coghlan (1987)	$CBR = 0.069 (CIV_{4.5kg})^2$	0.79	NA
Al-Amoudi et al. (2002)			
Lab tests	$CBR = 0.19 (CIV_{4.5kg})^{1.54}$	0.81	0.479
Field tests	$CBR = 1.35 CIV_{4.5kg})^{1.0115}$	0.85	0.142

[a] R^2 computed in log transformed space.

[b] SEE – standard error of the estimate computed in log transformed space.

[c] Not available.

$$CBR = K \cdot (CIV_{4.5kg})^2 \tag{2}$$

To account for soil type and local conditions Mathur and Coghlan (1987) introduced a coefficient K into their correlation. They reported K values ranging from 0.062 for a well-graded gravel with an admixture of silt (GW-GM) soil to 0.08 for a lean clay (CL) with an average value of 0.069 for all of the material types tested. They further recommended a small-scale local field investigation to determine the constant "K" for local soils and conditions.

Mathur and Coghlan (1987) conducted CBR value versus $CIV_{4.5kg}$ comparative tests only on laboratory samples, as did Alkire (1987). Al-Amoudi (2002) presented test results from both the laboratory and the field. A detailed examination of the test methods used in obtaining the equations in Table 1, and the range of the data, sheds some light on the value of the equations and the difficulty of determining the relationship between CIV and CBR.

Mathur and Coghlan's (1987) testing of unsoaked soil samples produced CBR values ranging from a low of about 1.5 for a lean clay to a high of nearly 70 for a poorly-graded gravel. The laboratory testing for CBR values was completed on the standard sample face (the bottom), and the CIV on the opposite face of the same sample. This methodology seems practical; however, the layered manner, with which samples are compacted, can result in the first layer (CBR test face) receiving more cumulative compactive energy from the compaction hammer than the top layer (the CIV face in Mathur and Coghlan's tests). This suggests that the sample strength/stiffness may not be equal on opposite ends of the sample in the mold. Thus, a correlation between soil strength at the top and bottom of the sample is implicit within the CBR-CIV correlation. Furthermore, despite the fact that determining CBR-CIV correlations in the CBR mold is consistent with the current ASTM test method (ASTM D5874) it is not clear if boundary effects from the mold have an influence on the resulting CIV or that the influence of the boundary is same for all soils. A similar influence will not be present in field testing.

Alkire (1987) prepared unsoaked samples of clays, silts, sands, and gravels in the laboratory, obtained the CBR value, and then obtained the CIV by averaging the CIV of the two sample faces. This practice may be less problematic than the approach used by Mathur and Coghlan (1987), but how Alkire (1987) dealt with sample damage from the CBR piston prior to obtaining the CIV was not addressed. The range in CBR values obtained was from a low of 1.0 to a high of over 140.

The laboratory samples tested by Al-Amoudi et al. (2002) were prepared and tested, unsoaked, in the same manner as Mathur and Coghlan's (1987) samples. The laboratory test soil was a carbonate soil that classified as an SC, although it plotted only slightly above the A-line on the plasticity chart, and had nearly 50% fines. The laboratory range in CBR values was from 4 to just over 100. Amoudi et al. (2002) did not use the ASTM D5874 method to obtain their laboratory CBR versus $CIV_{4.5kg}$ correlation, which requires paired samples.

The ASTM procedure postdates Mathur and Coghlan's (1987) work, but predates Al Amoudi's work. A total of 56 field tests on soils that classified as silty sand (SM) to silty gravel (GM) were conducted by Amoudi et al. (2002) to allow development of a field CBR-$CIV_{4.5kg}$ correlation. All the field CBR values were greater than 20, and ranged as high as 100. It is notable that the field correlation developed by Amoudi et al. (2002) is essentially linear.

While the literature provides a number of correlations between CBR and $CIV_{4.5kg}$, the range in correlations, and the range in CBR values included in the data used to develop the correlations suggest that for western Oregon, a testing more focused on the lower CBR values commonly found on forest road subgrades should be a target of this field work.

Field Site Location and Construction Methods

The field study portion of this research project was conducted within the McDonald Research Forest, managed by the Oregon State University College of Forestry. A majority of the field testing was conducted on a 183-meter (600 ft.) stretch of the newly constructed forest road (the 682 spur) located in Sec. 9, T 11S, R5W, Willamette Meridian. The 682 spur road section is mid-slope, and is built on side slopes varying from 30 to 60 percent with road grades ranging from 2 to 12 percent. The Natural Resource Conservation Service (NRCS) classifies the surrounding soils, including those used to construct the subgrade, as silty-clay loams, part of the Jory-Gelderman complex. Expected native soil depths are up to 254 cm (100 in.) (NRCS, 2006). Results of standard grain size distribution analysis for the road are shown in Figure 1. Atterberg limit testing (ASTM D 422, ASTM D 4318) resulted in a Plastic Index from 15 to 24% (Table 2). The results indicate that the subgrade soil type defined by the Unified Soil Classification System is a high to low plasticity silt (MH or ML) with or without sand and gravel depending on the location along the road. Subgrade soils tended to have a higher percentage of sand and thus lower plasticity from 0 to 60 meters along the 682 spur, with soil plasticity increasing past 60 meters as the road decreased in elevation and crossed a small drainage basin. Varying percentages of gravel (0 to 39 percent) were encountered in the subgrade soil past 40 meters with the highest amount found from 120 meters to the end of the test road.

The 682 spur was selected for study because it represents a typical hill-slope road constructed using current road building practices in western Oregon, had not experienced any operational traffic, and was easily accessible. The expected volume to be hauled over the road is 4,700 m^3 using a 36,000-kg GVW 5-axle log truck.

The 682 spur was constructed during the summer of 2006. The road was designed as out-sloping; thus, no ditch or relief culverts were installed. The road contract specified that the contractor use a smooth-wheeled roller with or without vibratory capability to compact the subgrade prior to surfacing the road with unsealed aggregate. The contract further specified that compaction of the subgrade would continue until visible deformation of the soil ceased or a minimum of three passes over the entire road prism was achieved. One pass was

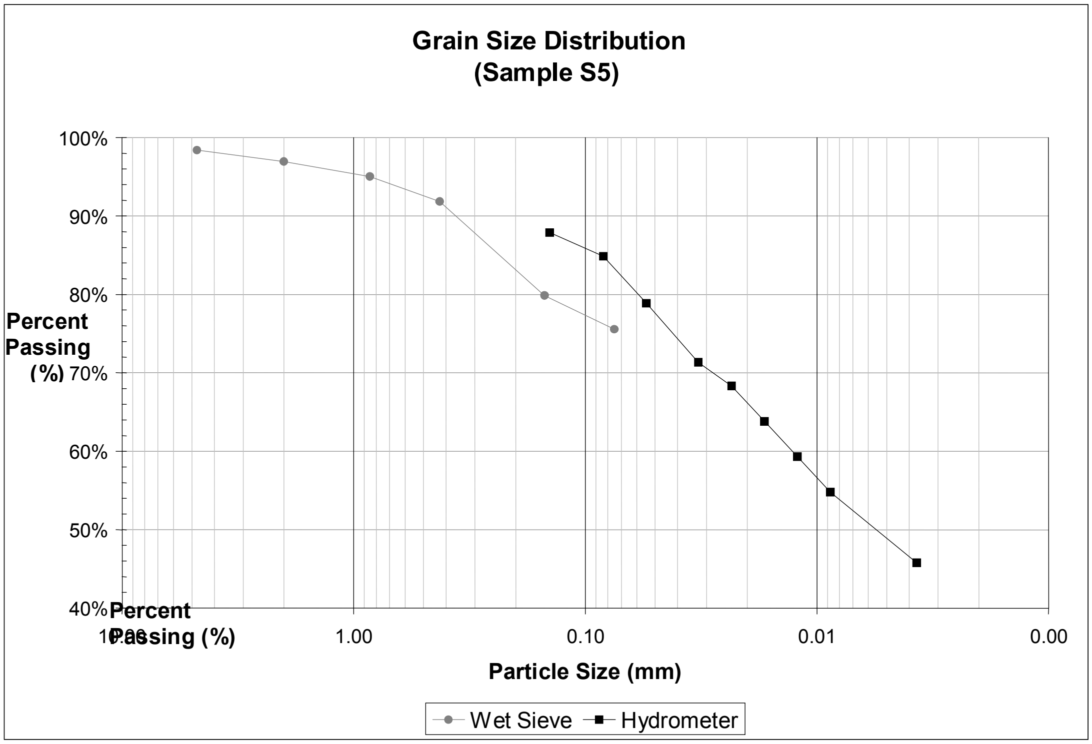

Figure 1. Represented grain size distribution from road.

defined as traveling back and forth over a given area. Neither control of soil moisture content during the compaction process nor checking of the achieved density was specified. After subgrade construction was finished and approved by the landowner, a 229-mm (9-in.) layer of 76-mm (3-in.) minus basaltic aggregate material was placed over the subgrade. The road contract specified that rock would be placed in 152-mm (6-in.) lifts, brought to uniform moisture content and compacted using the same vibratory roller used to compact the subgrade.

The testing along the Oak Creek Mainline was completed to extend the range of values of CBR and CIV_{20kg} that could be used in the correlation. The Oak Creek road is a mainline and has been used extensively over the past decades, as is the case with some of the spurs on which the testing was done. The subgrade soil types, road grades, between 5 and 10%, and side slopes between 20 and 60% are similar to the 682 spur, although the road position is closer to the ridge top than the 682 spur. Road aggregates along the Oak Creek Mainline varied in thickness and quality consistent with the traffic loads the road and spurs have experienced. Sampling of the Oak Creek road was completed in July of 2007.

Field Methods

The test section portion of the 682 spur road was divided into six 30-meter intervals beginning with station 0+00 at the end of the road, and ending at station 6+00. It was anticipated that seasonal drying of the subgrade soil would result in an increase in both the CBR and CIV_{20kg} values, thus allowing a correlation to be developed. Each trip to the field involved collection data within each of the six discrete segments. Since the samples were highly disturbed, there was no potential to replicate samples; however, the repeated samples were located as close as possible, in the same road segment to allow for reasonable comparison of the effect of time on soil properties.

Data collection occurred on April 28, May 10, May 17,

Table 2. Atterberg limits by road section.

	Road Segment						
	0	1	2	3	4	5	6
Liquid Limit =	54.40%	54.40%	59.79%	63.11%	52.63%	63.98%	60.69%
Plastic Limit =	39.15%	39.15%	40.54%	49.25%	38.59%	52.05%	37.34%
PI =	15.25%	15.25%	19.25%	13.86%	14.04%	11.93%	23.35%

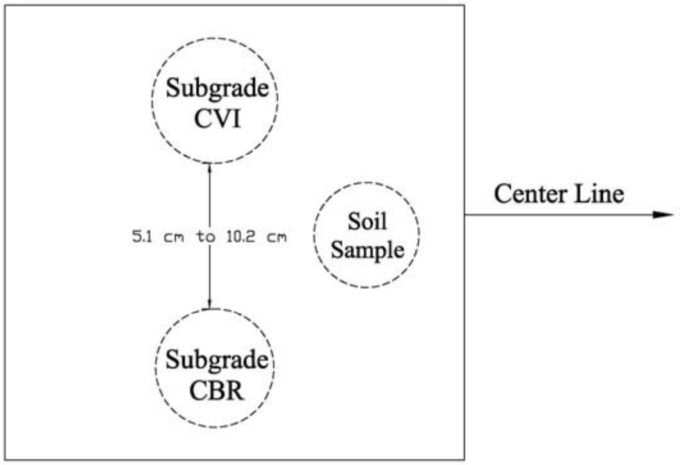

Figure 2. The type and approximate testing and sample locations for each test site.

May 31, June 27, July 10, and August 14 of 2007. Typically, the six sample sites were spaced approximately 30 meters apart. However, distances between sites varied on occasion due to the presence of rocks in the subgrade that were discovered when the aggregate surface was removed to expose the subgrade. Rocks present in the subgrade made it difficult to obtain soil samples that yielded a representative dry unit weight and moisture content of the subgrade soil. Further, the presence of rock directly under the CBR piston gave an artificially high CBR value that was not typical of the soil matrix. When rocks were discovered, the sample site was moved forward or backward by 15 meters to avoid the rock. After data was collected at a given location, a sample site was moved approximately 1.5 meters forward for the next round of data collection within the road segment to sample in an undisturbed site.

Site visits for the data collection ranged from every two weeks to up to more than a month between visits. During extended time periods between replicate data collection the moisture content of the subgrade was monitored to assess whether any significant subgrade drying had occurred.

Data collection at each of the six near-replicate sample sites was carried out in the same manner. All sampling and testing was done on the road centerline in order to limit the influence of the test vehicle travel over the road. Data obtained at road centerline included CBR value, $\text{CIV}_{20\text{kg}}$, dry unit weight, and moisture content (ASTM D4429, ASTM D5874, ASTM D698, ASTM D2216). During the duration of data collection, representative soil samples were taken from each subgrade excavation for further laboratory analysis to determine the subgrade soil properties. Upon exposure of the subgrade, the in-situ CBR value of the subgrade was obtained via a truck-mounted CBR device (ASTM D4429). During the CBR test an 89 N (20 lb) surcharge load was placed on the subgrade to mimic the weight of the overlying aggregate. The CBR piston was attached to an S-type Interface load cell having an 8.9 kN (2 kip) capacity. Displacement was measured using a linear variable differential transformer. Force and displacement measurements were logged in half second intervals using a Campbell Scientific Micro-logger. These data were immediately transferred to a laptop computer where the data was inspected for inconsistencies prior to moving to the next sample site. Upon completion of the CBR test, a 20-kg Clegg Hammer was used to obtain the $\text{CIV}_{20\text{kg}}$ (ASTM D 5874) of the subgrade and aggregate surface. The aggregate surface $\text{CIV}_{20\text{kg}}$ was obtained as part of another study. Typically, the CIV of the subgrade was obtained 5 to 10 cm from where the CBR test was performed to ensure that the soil being tested was not influenced by the CBR test (Figure 1). To obtain the $\text{CIV}_{20\text{kg}}$ the 20-kg Clegg Hammer was dropped from a height of 30 cm four times. Although all CIVs were recorded, the fourth reading was taken as the $\text{CIV}_{20\text{kg}}$. With subgrade strength measurements completed, soil samples were collected at each sample site using a standard impact soil sampler at approximate location shown in Figure 2. The soil sampler yielded a cylindrical sample 5.4 cm diameter and 6 cm long. Soil samples were trimmed square in the field using a putty knife, placed in a Ziploc bag, and stored in a cooler for later laboratory determination of dry unit weight and moisture content (ASTM D698, ASTM D2216). The hole dug to expose the subgrade was then filled and data collection resumed at the next sample site.

The testing along the Oak Creek Mainline was conducted using the same method as detailed above in July of 2007, with the exception that there was no replication of testing through the summer season.

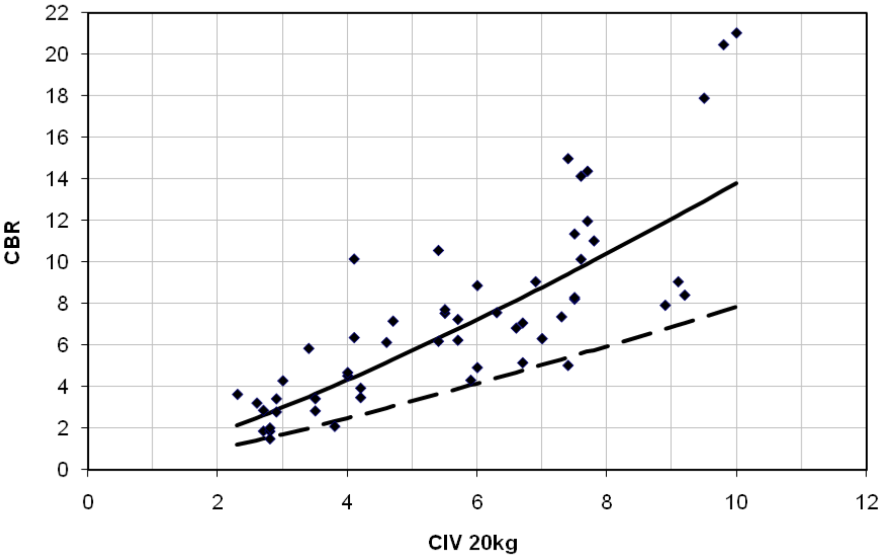

Figure 3. CBR — CIV relationship with the back-transformed regression equation and back-transformed lower one-tailed 90% prediction limit

Table 3. All in-situ CIV, Moisture Content and CBR data.

Collection Date	Location (STA)	M.C. (g/g)	Dry Unit Weight (kN/m3)	Subgrade CBR (%)	Subgrade CIV (gravities)
4/28/2007	0+00	41.60%	11.3	6.34	4.1
4/28/2007	1+00	37.20%	8.7	11.33	7.5
4/28/2007	2+50	47.30%	10.7	11.59	------
4/28/2007	3+00	37.80%	-----	9.18	5.4
4/28/2007	4+00	60.00%	-----	2.39	2.9
4/28/2007	5+00	41.80%	-----	3.08	3.0
5/10/2007	0+05	38.60%	11.5	7.14	4.7
5/10/2007	1+05	42.70%	10.7	14.35	7.7
5/10/2007	2+05	49.80%	10.3	19.92	7.4
5/10/2007	2+55	45.70%	11.0	8.21	6.0
5/10/2007	4+05	46.30%	13.6	3.34	6.0
5/10/2007	5+05	44.20%	10.9	2.35	3.5
5/17/2007	0+10	51.90%	10.2	19.30	4.6
5/17/2007	1+10	37.10%	12.8	6.22	9.2
5/17/2007	2+10	51.00%	9.5	17.75	5.6
5/17/2007	2+60	46.50%	11.1	1.56	3.8
5/17/2007	4+10	46.00%	9.4	1.42	2.8
5/17/2007	5+10	44.60%	10.6	3.00	3.5
5/31/2007	0+15	51.20%	14.4	6.01	5.4
5/31/2007	1+15	36.30%	12.4	4.9	7.0
5/31/2007	2+15	49.90%	10.4	7.65	7.7
5/31/2007	3+05	42.50%	9.3	5.24	4.6
5/31/2007	4+15	39.50%	10.6	1.22	2.8
5/31/2007	5+15	43.90%	10.5	1.52	2.8
6/27/2007	0+20	38.50%	11.5	4.5	4.0
6/27/2007	1+20	37.00%	12.4	7.54	6.3
6/27/2007	2+20	51.80%	10.4	17.86	9.5
6/27/2007	3+10	41.30%	11.1	7.05	6.7
6/27/2007	4+20	40.70%	10.9	2.84	2.7
6/27/2007	5+20	46.30%	10.4	3.28	2.9
7/10/2007	0+25	38.70%	12.0	10.12	4.1
7/10/2007	1+25	36.20%	12.8	6.17	7.3
7/10/2007	2+45	48.10%	10.0	14.11	7.6
7/10/2007	3+15	41.30%	11.1	7.22	5.5
7/10/2007	4+25	37.90%	12.8	1.64	2.7
7/10/2007	5+25	42.10%	10.9	2.28	2.6
8/14/2007	0+30	36.70%	12.0	5.82	3.4
8/14/2007	1+30	34.70%	12.6	19.99	7.0
8/14/2007	2+40	46.30%	10.7	9.74	7.6
8/14/2007	3+20	40.60%	11.0	3.23	4.2
8/14/2007	4+30	37.00%	11.4	3.61	2.3
8/14/2007	5+30	45.30%	10.1	2.95	4.2
Mean =		43.2%	11.1	7.30	5.1
Standard Deviation =		5.6%	1.2.0	5.50	2.0

Table 4. Comparison of 4.5- and 20-kg Clegg Hammer areas and energy inputs.

Hammer Mass (kg)	Drop Height (cm)	Hammer Diameter (cm)	Impact Energy (N-m)	Hammer Area (cm2)	Energy per unit Area (J/cm2)
4.5-kg	45	5	19.9	19.6	1.01
20-kg	30	13	58.9	133	0.44

CBR-CIV Correlation

Measurements of subgrade CBR value and CIV_{20kg} collected along the 682 spur road and the Oak Creek Mainline were compiled for regression analysis to establish a correlation between the two strength measurements (Table 3). The desired correlation would allow estimation of the CBR value from the CIV_{20kg} exclusively; hence, the CIV_{20kg} was treated as the sole independent variable. The greater of the CBR at 2.54 mm or 5.08 mm of piston penetration was used as the dependent variable. A scatter plot of the raw CBR-CIV_{20kg} data indicated that the data was heteroscedastic as is common with zero bounded data (negative CBR values or CIV_{20kg} are not possible giving rise to lower variance near zero). Since earlier correlations between CBR and CIV_{20kg} were nonlinear (Table 1), and transformation was indicated by heteroscedasticity, the data was transformed into log-log space for regression. During the regression analysis process, four data points were identified and discarded from the analysis (Table 3, Figure 3). These data points were discarded because rocks were noted as being present under the CBR piston and cause an artificially high CBR point that would not be captured by the Clegg hammer with is larger testing area. The presence of rock directly under the CBR piston gave an artificially high CBR that was not typical of the overall soil matrix structure.

Linear regression in log transformed space resulted in the following equation:

$$\log CBR = \log \beta_0 + \beta_1 \log CIV_{20kg} \tag{3}$$

where β_0 = -0.128, and β_1= 1.268 (R^2 = 0.71, standard error of 0.344, and p-value for β_1 = 0.0001).

Reverse transforming of Equation (3) produces an equation of a form similar to those presented in Table 1:

$$CBR = 0.744 \times {CIV_{20kg}}^{1.268} \tag{4}$$

CBR-CIV_{20kg} Correlation

The in-situ CBR-CIV_{20kg} correlation presented in Equation 4 has the same form as previous correlations for the 4.5-kg Clegg hammer, but has an R^2 that is lower than the laboratory correlations presented in Table 1. The lower R^2 for the 20-kg hammer is likely due to greater variability encountered in the field, a smaller range in soil strength (CBR and CIV), and the effect of the larger 20 kg hammer. Less variability is expected in the laboratory because soil samples are free of organic debris, large rocks, and soil aggregates that may be present in the field. Sample preparation in the laboratory could result in a more uniform soil matrix within the hemisphere of influence of the hammer which in turn results in lower variability than that encountered in the field.

While the larger hammer will impact on a larger soil surface area, it is not clear that this will result in greater variability in response. The larger area of the 20-kg hammer may tend to average short interval variations in the soil, but the impact energy of the 4.5-kg hammer is about 2.5 times that of the 20-kg hammer on a per unit area basis (Table 4). It may be that the higher unit area impact energy of the 4.5-kg hammer tends to reduce variability in response, but we leave this question to be answered in the future.

While it is apparent that a strong correlation between the CBR and CIV_{20kg} exists, the variance to the correlation is large enough that a lower bound to the correlation is necessary for conservative and practical field application. For this example, we have selected a lower bound that can be obtained from the lower one-tailed prediction limit for the correlation, as shown in Figure 3. The lower one tailed 90% prediction limit illustrated in Figure 3 provides a CBR-CIV_{20kg} function that will only exceed the actual field CBR 10% of the time. The other alternative is to conduct multiple tests at a single site and use the average for predicting CBR.

In construction control mode, the field technician would have in hand the value of the unsoaked CBR that corresponds the soaked design CBR, that was the basis for determining the aggregate properties and thickness design for the road. This unsoaked CBR corresponds to a CIV_{20kg} from the correlation in Figure 3. To account for variability, the field technician need only verify that the CIV_{20kg} indicated by the lower 90% prediction limit is achieved for the subgrade to be 90% confident that the design CBR — or greater — is achieved for the subgrade. This will allow for the subgrade evaluation to be accomplished entirely from field data collected during construction.

Conclusions

CBR-CIV_{20kg} correlation presented in Figure 3 may be applied within the McDonald Research Forest and could be applicable for similar soil types in other areas. Prior to use in other areas with similar soil types, in-situ CBR testing is recommended to determine the validity of the correlation.

Standard compaction control involves field sampling and testing to verify that the specified dry density is achieved within the specified water content range. These specifications are based on desired engineering properties such as CBR. While rapid assessment of field compaction can be obtained with a nuclear densometer, more conventional methods involve time-consuming sampling and testing for both density and moisture content. Use of the Clegg impact hammer does not provide the additional information that standard compaction control would provide (i.e. moisture content and dry unit weight). Knowledge of moisture content and density can allow the design engineer to propose remedies for failure to meet the specifications, such as adjusting moisture content or employing greater compaction energy in order to obtain the specified dry unit weight. The Clegg impact hammer has the advantage of providing rapid feedback to construction personnel with no further soil testing. A Clegg impact hammer test requires only a fraction of a minute unless the compacted surface is rough, requiring trimming for a uniform contact of the hammer.

Design standards for aggregate surfaced forest road design most commonly are based on soaked subgrade CBR values. Only modest laboratory testing procedural changes need to be implemented to allow use of a CBR value versus CIV_{20kg} correlation for construction control. Specifically, the as-compacted, unsoaked CBR value that corresponds to the design, soaked CBR value will be required as part of future research. This could be obtained from paired laboratory samples, or from a laboratory correlation between as-compacted, unsoaked CBR and the soaked CBR used for. Construction specifications will then be written in terms of as-compacted, unsoaked CBR. Then, the field CIV_{20kg} obtained during construction can be used to verify achievement of the desired subgrade properties. This is suggested as part of future research project.

As originally shown by B. Clegg (1976), the Clegg Hammer shows promise as a tool to quickly measure soil strength during construction. It shows good correlation with the in-situ CBR and, with a lower-bound confidence interval, can quickly develop a useful estimate of the strength of the soils. It does not offer guidance that traditional compaction control provides on density, moisture content, or other soil properties once the initial correlation has been developed, but it offers a tool that can easily locate weak areas that will need additional compaction during construction.

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