KSE form 300, 20 AUGUST 2014
K100UM300

PATENT NO. 5,313,825

Meets ASTM D6951

KSE DCP

DYNAMIC CONE PENETROMETERS

K-100 Models

WITH QUICK CONNECT PIN

USER'S MANUAL

Kessler Soils Engineering Products, Inc.
17775 Running Colt Place, Leesburg, VA 20175
SALES: (703) 569-2583 or (800) 569-7303
www.kesslerdcp.com

SAFETY *NOTICE*

DO NOT PUT HAND NEAR THE ANVIL WHEN HAMMER IS RAISED

KEEP ONE HAND ON THE HANDLE WHILE OPERATING THE DCP

ALWAYS SECURE THE HAMMER AND/OR THE ASSEMBLED DCP INSTRUMENT

WHEN PLACING IT ON ANY FLAT ELEVATED SURFACE TO PREVENT IT FROM ROLLING OFF AND CAUSING PERSONAL INJURY OR DAMAGE TO THE INSTRUMENT.

12. PARTS LIST

ITEM	DESCRIPTION
K010	K-100 User's Manual & Software
K1312	Drive Rod, 12" - Stainless
K1330	Drive Rod, 30" - Stainless
K133775	Drive Rod, 37 3/4" - Stainless
K133775S	Drive Rod, 37 3/4" - Spring Steel
K1348	Drive Rod, 48" - Stainless
K1348S	Drive Rod, 48" - Spring Steel
K1724	Extension Rod, 24" - Stainless
K450	Pin with Clip, 2 per pkg
K500	Vertical Scale, 40
K510	Foot, Vertical Scale holder
K530	Upper Attachment, Vertical Scale holder
K550	Measuring Rod, 40", aluminum
K700	Hardened Point with flats, silver
K705	5-Pack, Hardened Points w/ flats (silver)
K800	Cone Adapter with flats, silver
K900	25 Disposable Cones

11. WARRANTY

1. KESSLER SOILS ENGINEERING PRODUCTS, INC. guarantees this product to be manufactured in the U.S. A. to the specifications and standards developed by the Department of the Army, Corps of Engineers, Waterways Experiment Station and recorded under patent number 5,313,825 entitled "Dual Mass Dynamic Cone Penetrometer."

2. KESSLER SOILS ENGINEERING PRODUCTS, INC. warrants this product to be free from defects in material and components for one (1) year from the date of first purchase, provided the product is used, operated and maintained in accordance with all applicable instructions. To claim under this warranty the Bill of Sale and cancelled check or credit card receipt must be presented.

3. This warranty does not apply to parts that are not in original condition because of normal wear and tear, or parts that fail or become damaged as a result of misuse, accidents, lack of proper maintenance or defects caused by improper use. Shipping costs relating to repairing a KESSLER DCP will be the responsibility of the purchaser.

4. To the full extent allowed by the law of the jurisdiction that governs the sale of the product, this express warranty excludes any and all other expressed warranties and limits the duration of any and all implied warranties, including warranties of merchantability and fitness for a particular purpose to one (1) year from the date of first purchase. The liability of KESSLER SOILS ENGINEERING PRODUCTS, INC. is limited to the purchase price of the product and does not cover any other damages whatsoever including indirect, incidental or consequential damages.

5. Limitations herein do not apply in states that do not allow a limitation on how long an implied warranty lasts or an exclusion or limitation of incidental or consequential damage.

INDEX

PART I

DCP With Vertical Scale

the Dynamic Cone Penetrometer (DCP), Technical Report No. GL-94-17, Air Force Civil Engineering Support Agency, U.S. Air Force, Tyndall Air Force Base, Florida.

(8) Siekmeier, J.A., Young, D., and Beberg, D., (1999), Comparison of the Dynamic Cone Penetrometer with Other Tests During Subgrade and Granular Base Characterization in Minnesota, Nondestructive Testing of Pavements and Backcalculation of Moduli: Third Volume, ASTM STP 1375, S.D. Tayabji and E.O. Lukanen, Eds., American Society for Testing and Materials, West Conshohochen, Pennsylvania.

(9) Livneh, M,. (1999), The Israeli Experience with the Regular and Extended Dynamic Cone Penetrometer for Pavement and Subsoil Strength Evaluation, Nondistructive Testing of Pavements and Backcalculation of Moduli, ASTM STP 1375, S.D. Tayabji and E.O. Lukanen, Eds., American Society for Testing and Materials, West Conshohochen, Pennsylvania.

(10) De Beer M. (March 2000) Dynamic Cone Penetrometer (DCP). The Development of DCP pavement technology in South Africa. Video Tape Series from RSA/US Pavement Technology Workshop. Technology Transfer Office, University of California, Berkeley, California.

(11) ASTM D 6951-03 Standard Test Method of Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications.

(12) Portland Concrete Association (1955), Design of Concrete Airport Pavement, Portland Cement Association, P8.

9. MAINTENANCE

Testing with the KESSLER DCP causes wear on the metal parts that make up the device. In order to ensure maximum service life, periodic inspections of the KESSLER DCP for fatigue or damage are recommended. Any parts found to be fatigued or damaged should be repaired by the manufacturer, or replaced with Kessler DCP parts. The KESSLER DCP should be kept clean and all soil removed from the Drive Rod and Hardened Point before each test. The drive rod should be kept clean and lubricated with oil.

10. REFERENCES

(1) Scala, A.J., (1956), Simple Methods of Flexible Pavement Design Using Cone Penetrometers, Proceedings of the Second Australian Soil Mechanics Conference, Christ Church, New Zealand. New Zealand Engineer. 11(2) pages 34-44.

(2) Kleyn, E.G., (July.1975), The Use of the Dynamic Cone Penetrometer (DCP), Report 2/74, Transvaal Roads Department, Pretoria, South Africa. Page 35.

(3) METHOD ST6: Measurement of the *In Situ* Strength of soils by the Dynamic Cone Penetrometer (DCP) (1984) Special Methods for Testing Roads, Draft TMH6, Technical Methods for Highways (TMH), ISBN 0 7988 2289 9, Pages 19 to 24, 1984.

(4) Portland Concrete Association (1995), Design of Concrete Airport Pavement, Portland Cement Association.

(5) De Beer, M., (1991), Use of the Dynamic Cone Penetrometer (DCP) in the Design of Road Structures, Research Report DPVT-18, Roads and Transport Technology, CSIR, South Africa.

(6) Webster, S.L., Grau, R.H. Williams, T.P., (May 1992), Description and Application of Dual Mass Dynamic Cone Penetrometer, Report GL-92-3, Department of the Army, Washington DC, Pg 19.

(7) Webster, S.L., Brown, R.W., Porter, J.R. (April 1994), Force Projection Site Evaluation Using the Electric Core Protection (ECP) and

Thank you for your purchase of a Kessler DCP (Dynamic Cone Penetrometer), licensed to Kessler Soils Engineering Products, Inc. by the U.S. Army Corps of Engineers (Patent No. 5,313,825).

The Kessler DCP is a durable and reliable Penetrometer designed for field soil testing and measuring.

1. APPLICATION

1.1 This application describes measurement of the penetration rate of the KESSLER DCP (Dynamic Cone Penetrometer) with a Single-Mass or Dual-Mass Hammer and quick-connect Drive Rod in field soil testing **using a Vertical Scale.**

1.2 The KESSLER DCP is driven into the soil by dropping either a Single-Mass 17.6 lb (8kg) Hammer or a Dual-Mass Hammer from a height of 22.6 in (575mm). To convert the Dual-Mass Hammer from a 17.6 lb hammer to a 10.1 lb Hammer, remove the hexagonal set screw and the outer steel sleeve *(as shown in Fig. 2).* The outer steel sleeve is designed to slide over the DCP handle for ease of conversion during testing. The cone penetration caused by one blow of the 17.6 lb (8 kg) hammer is essentially twice that caused by one blow of the 10.1 lb (4.6 kg) hammer. The 10.1 lb (4.6 kg) hammer is used in weaker soils having a CBR value of 10 or less and can be used on soils up to CBR 80. The 17.6 lb (8 kg) hammer penetrates high strength soils quicker. The depth of cone penetration is measured at selected penetration or hammer drop intervals and the soil shear strength is reported in terms of DCP index. The DCP index is based on the average penetration depth resulting from one blow of the 17.6 lb (8 kg) hammer. The average penetration per hammer blow of the 10.1 lb (4.6 kg) hammer must be multiplied by 2 in order to obtain the DCP index value from the correlation equation in paragraph 4.

1.3 The KESSLER DCP can be used to estimate the strength characteristics of fine and grained soils, granular construction materials and weak stabilized or modified materials.

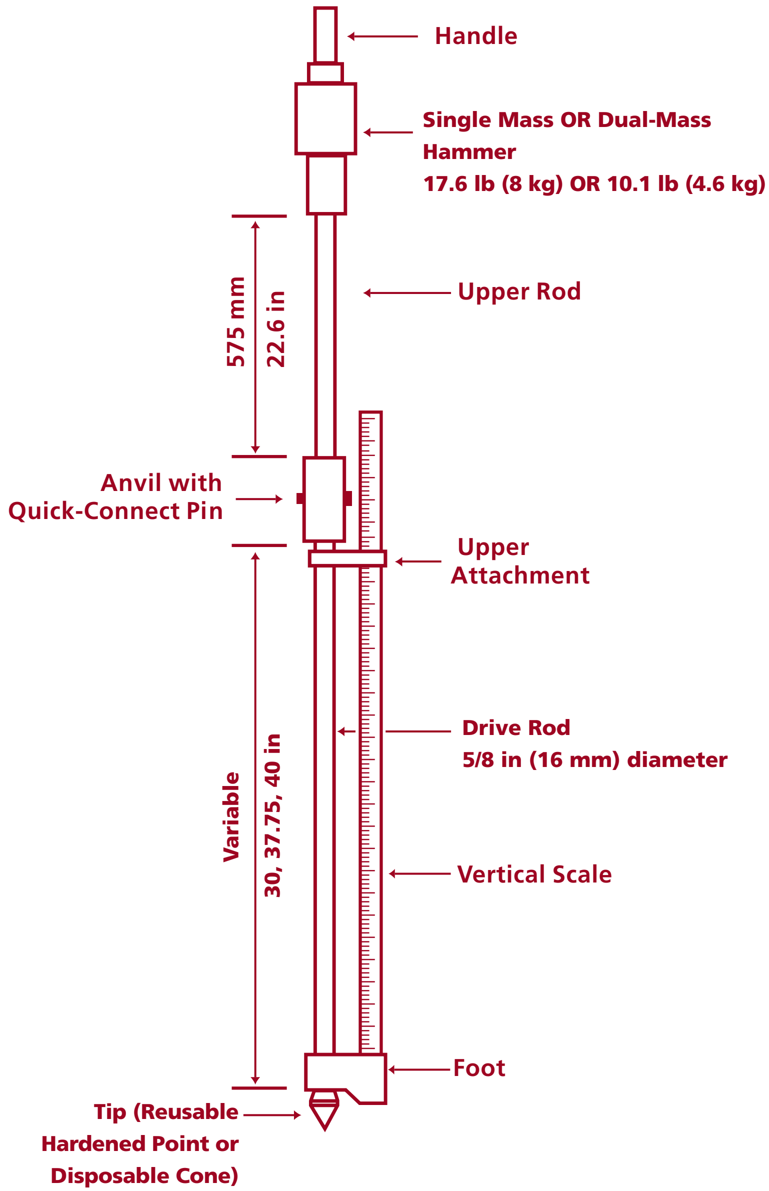


Figure 1–Schematic of DCP Device

▶ PART III

Maintenance
References
Warranty
Parts List

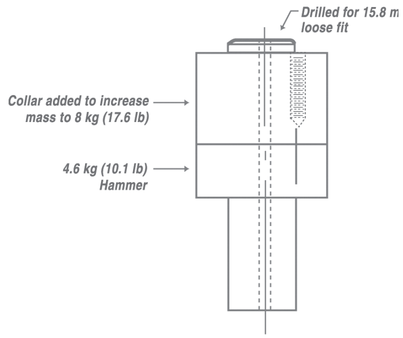
1.4 The KESSLER DCP can be used to estimate the strength of *in situ* materials underlying a bound or highly stabilized layer by first drilling or coring an access hole.

NOTE: The DCP may be used to assess the density of a fairly uniform material by relating to penetration rate on the same material. In this way under compacted or "soft spots" can be identified, even though the DCP does not measure density directly.

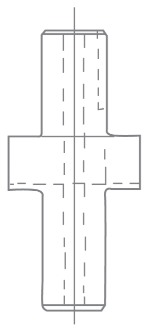
A field DCP measurement results in a field or *in situ* CBR and will not normally correlate with the laboratory or soaked CBR of the same material. The test is thus intended to evaluate the *in situ* strength of a material under existing field conditions.[1]

2. DESCRIPTION

2.1 The KESSLER DCP in Fig.1 consists of an upper assembly with a Single Mass or Dual-Mass Hammer (Fig. 2), a Drive Rod and a tip. The Drive Rod is held in place with a Quick-Connect Pin (Fig. 3) through the anvil. The tip consists of an Adapter and Disposable Cone (Fig. 4) or reusable Hardened Point (Fig. 5). The DCP is constructed of stainless steel, with the exception of the tip. The Hardened Points and the Adapters for the Disposable Cones are heat treated steel. The Disposable Cones are plated steel.



17.6 lb (8kg) Hammer



10.1 lb (4.6kg) Lower Hammer

Figure 2–Dual-Mass Hammer

[1]**METHOD ST6 (1984)** Measurement of the *In Situ* Strength of Soils by the Dynamic Cone Penetrometer (DCP) (1984) Special Methods for Testing Roads, Draft TMH 6, Technical Methods for Highways (TMH), Pretoria, South Africa. ISBN 0 7988 2289 9,Page 20.

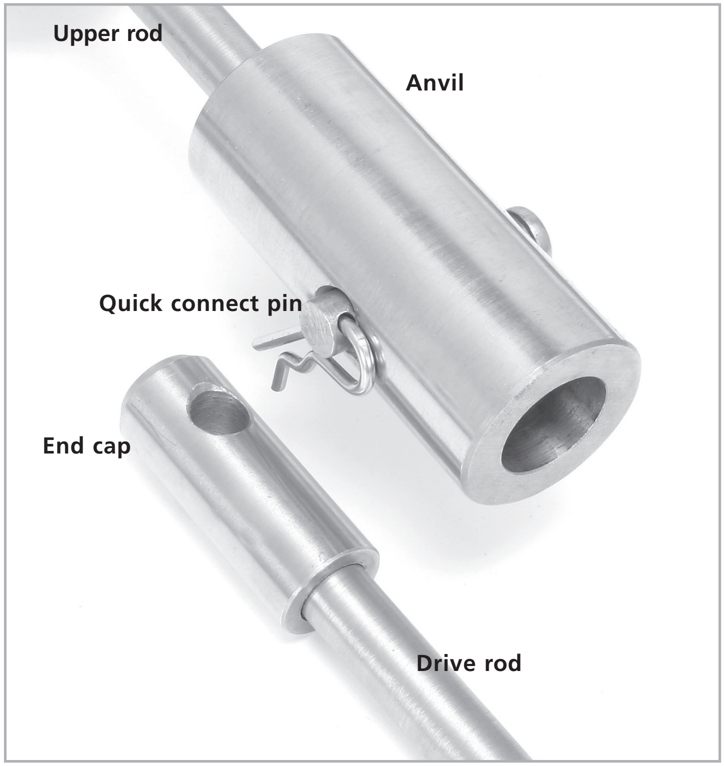


Figure 3–Quick Connect Assembly
(Patent Pending)

Table -5 - Tabulated Correlation of blows per 6" penetration verses CBR and PSF

Hammer 17.6 lbs Blows/6"	Hammer 10.1 lbs Blows/6"	CBR Soil type Other	CBR Soil type CL	CBR Soil type CH	PSF Soil type Other	PSF Soil type CL	PSF Soil type CH
	1	0	0	1	340	60	600
1	2	1	0	2	560	150	950
	3	2	0	3	760	260	1240
2	4	2	1	5	940	390	1500
	5	3	1	6	1110	520	1740
3	6	4	1	7	1280	660	1960
	7	4	2	8	1430	810	2170
4	8	5	2	9	1580	970	2370
	9	6	3	10	1730	1140	2570
5	10	6	4	11	1870	1310	2750
	11	7	4	13	2000	1480	2930
6	12	8	5	14	2140	1660	3110
	13	9	6	15	2270	1850	3280
7	14	9	7	16	2400	2040	3440
	15	10	8	17	2520	2240	3600
8	16	11	11	18	2650	2650	3760
	17	12	18	19	2770	2770	3920
9	18	12	19	21	2890	2890	4070
	19	13	21	22	3010	3010	4220
10	20	14	22	23	3120	3120	4360
	21	15	23	24	3240	3240	4500
11	22	15	24	25	3350	3350	4650
	23	16	25	26	3470	3470	4790
12	24	17	27	27	3580	3580	4920
	25	18	28	29	3690	3690	5060
13	26	19	29	30	3800	3800	5190
	27	19	30	31	3910	3910	5320
14	28	20	32	32	4010	4010	5450
	29	21	33	33	4120	4120	5580
15	30	22	34	34	4220	4220	5710
	31	23	36	35	4330	4330	5830
16	32	23	37	37	4430	4430	5960
	33	24	38	38	4530	4530	6080
17	34	25	39	39	4640	4640	6200
	35	26	41	40	4740	4740	6320
18	36	27	42	41	4840	4840	6440
	37	28	43	42	4940	4940	6560
19	38	28	45	43	5040	5040	6680
	39	29	46	45	5130	5130	6790
20	40	30	47	46	5230	5230	6910

Table -4 - Tabulated Correlation of blows per 4" penetration verses CBR and PSF

Hammer 17.6 lbs Blows/4"	Hammer 10.1 lbs Blows/4"	CBR			PSF		
		Soil type			Soil type		
		Other	CL	CH	Other	CL	CH
	1	1	0	2	460	110	780
1	2	2	0	3	760	260	1240
	3	3	1	5	1030	450	1620
2	4	4	1	7	1280	660	1960
	5	5	2	9	1510	890	2270
3	6	6	3	10	1730	1140	2570
	7	7	4	12	1940	1390	2840
4	8	8	5	14	2140	1660	3110
	9	9	7	15	2330	1950	3360
5	10	10	8	17	2520	2240	3600
	11	11	11	19	2710	2710	3840
6	12	12	12	21	2890	2890	4070
	13	13	13	22	3070	3070	4290
7	14	15	15	24	3240	3240	4500
	15	16	16	26	3410	3410	4720
8	16	17	17	27	3580	3580	4920
	17	18	18	29	3740	3740	5120
9	18	19	19	31	3910	3910	5320
	19	21	21	33	4070	4070	5520
10	20	22	22	34	4220	4220	5710
	21	23	23	36	4380	4380	5900
11	22	24	24	38	4530	4530	6080
	23	25	25	39	4690	4690	6260
12	24	27	27	41	4840	4840	6440
	25	28	28	43	4990	4990	6620
13	26	29	29	45	5130	5130	6790
	27	30	30	46	5280	5280	6970
14	28	32	32	48	5420	5420	7140
	29	33	33	50	5570	5570	7310
15	30	34	34	51	5710	5710	7470
	31	36	36	53	5850	5850	7640
16	32	37	37	55	5990	5990	7800
	33	38	38	57	6130	6130	7960
17	34	39	39	58	6270	6270	8120
	35	41	41	60	6400	6400	8280
18	36	42	42	62	6540	6540	8430
	37	43	43	63	6670	6670	8590
19	38	45	45	65	6810	6810	8740
	39	46	46	67	6940	6940	8890
20	40	47	47	69	7070	7070	9040

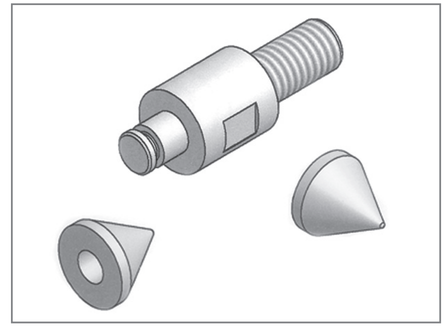


Figure 4–Adapter with two Disposable Cones

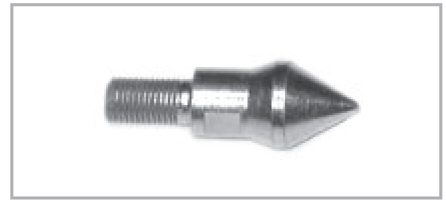


Figure 5– Reusable Hardened Point

2.2 The instrument is manufactured to the following specifications:

(1) Hammer weight measurement of 17.6 lb (8kg) tolerance is 0.022 lb(0.010kg).

(2) Hammer weight measurement of 10.1 lb (4.6kg) tolerance is 0.022 lb (0.010kg).

(3) Drop of hammer measurement of 22.6 in (575 mm) tolerance is 0.039 in (1.0 mm)

(4) Tip included angle measurement of 60 degrees; tolerance is 1 degree.

(5) Tip base diameter measurement of 0.790 in (20 mm); tolerance is 0.010 in (0.25mm)

NOTE: The Disposable Cone tip shown in Figure 4 is held in place with an o-ring. Use Disposable Cone tips in hard and cohesive soils to allow easy extraction of the instrument. The Disposable Cone tip is designed to slide off the Adapter when the Drive Rod is pulled upward after completion of the test.

2.3 Replacement and Optional DCP equipment can be found at **www.kesslerdcp.com,** including:

- 12”, 30” and 37.5” Drive Rods
- 48” Drive Rod
- 12” and 24” Extension Rods
- Magnetic Ruler
- Magnetic Ruler Printer

2.4 Other equipment used to make an access hole through a bound layer may include:

- a rotary hammer drill or coring appartus capable of drilling a minimum diameter hold of 1 inch (25mm). A larger hold make be required depending on the underlying material or the need for additional tests or sampling.
- a wet/dry vacuum or suitable alternative to remove loose material and fluid if an access hole is made before testing.
- a field power supply to power above items.

Table -3 - Tabulated Correlaltion of blows per 2” penetration verses CBR and PSF

Hammer 17.6 lbs Blows/2”	Hammer 10.1 lbs Blows/2”	CBR Soil type Other	CBR Soil type CL	CBR Soil type CH	PSF Soil type Other	PSF Soil type CL	PSF Soil type CH
	1	2	0	3	760	260	1240
1	2	4	1	7	1270	660	1960
	3	6	3	10	1720	1130	2560
2	4	8	5	14	2130	1660	3100
	5	10	8	17	2520	2230	3600
3	6	12	12	21	2880	2840	4060
	7	15	15	24	3240	3240	4500
4	8	17	17	27	3570	3570	4920
	9	19	19	31	3900	3900	5320
5	10	22	22	34	4220	4220	5700
	11	24	24	38	4530	4530	6070
6	12	27	27	41	4830	4830	6430
	13	29	29	45	5130	5130	6790
7	14	32	32	48	5420	5420	7130
	15	34	34	51	5700	5700	7460
8	16	37	37	55	5980	5980	7790
	17	39	39	58	6260	6260	8110
9	18	42	42	62	6530	6530	8420
	19	45	45	65	6800	6800	8730
10	20	47	47	69	7060	7060	9030
	21	50	50	72	7320	7320	9330
11	22	53	53	75	7580	7580	9620
	23	55	55	79	7840	7840	9910
12	24	58	58	82	8090	8090	10200
	25	61	61	86	8340	8340	10480
13	26	63	63	89	8580	8580	10750
	27	66	66	92	8830	8830	11020
14	28	69	69	96	9070	9070	11290
	29	72	72	99	9310	9310	11560
15	30	74	74	100	9550	9550	11820
	31	77	77		9780	9780	
16	32	80	80		10020	10020	
	33	83	83		10250	10250	
17	34	86	86		10480	10480	
	35	89	89		10710	10710	
18	36	91	91		10930	10930	
	37	94	94		11160	11160	
19	38	97	97		11380	11380	
	39	100	100		11600	11600	
20	40	100	100		11820	11820	

8. CORRELATIONS

8.1 Tables 3, 4, and 5 are derived from the following equation recommended by the US Army Corps of Engineers, where PR is the DCP penetration rate in mm per **5.2** This procedure is used to assess the in place strength of undisturbed soil and/or compacted materials. The penetration rate can blow:

$$CBR = 292 / PR^{1.12}$$

This equation is used for all soils except for CL soils below CBR 10% and CH soils. For these soils, the following equations are recommended by the US Army Corps of Engineers[3]. Selection of the appropriate correlation is a matter of professional judgment.

$$\text{CL soils } CBR < 10\text{: } CBR = 1 / (0.017019*PR)^2$$
$$\text{CH soils: } CBR = 1/ (0.002871*PR)$$

For analysis of shallow foundations an estimate of bearing capacity can be made from the following equation adapted from the Portland Cement Association (PCA)[12] showing the relationship between bearing capacity and CBR.

$$q= 3.794*CBR^{0.664}$$

q = Bearing Capacity (psi) ultimate

8.2 If a distinct layering exists within the material tested, a change of slope on a graph of penetration/blow vs. depth will be observed for each layer. The exact interface is difficult to define because, in general, a transition zone exists between layers. The layer thickness can be defined by the intersection of the lines representing the average slope of adjacent layers. Once the layer thicknesses have been defined, the average penetration rate per layer is calculated.

3. PROCEDURES

3.1 Equipment Check

3.1.1 Before beginning a test, check to ensure the Drive Rod is straight by rolling the rod on a flat surface. Note: The Drive Rod may bend if driven beyond refusal (see para 3.3.3).

3.1.2 The Hardened Point must be checked to ensure the 3 mm flat is discernible. The flat area will become rounded after about 250 tests and the tip should be replaced. Rarely, if ever, does the Hardened Point wear to the extent that the diameter fails to meet specifications (see para 2.2).

3.1.3 The Adapter o-ring should be should be clean and free of cuts or nicks. Each pack of 25 Disposable Cones contains a replacement o-ring.

3.2 Assembling

3.2.1 *Vertical Scale-* Secure the black delrin Upper Attachment by tightening the screw just below the end cap. Next, place the foot over the end of the Drive Rod. Slide the Vertical Scale through the square hole in Upper Attachment and into the foot.

3.2.2 *Tip-* Tighten the tip securely with the wrenches.

3.2.2.1 The reusable Hardened Point is used in soft, non-cohesive material, i.e. where the DCP advances more than 1/2" per blow (CBR <18%).

3.2.2.2 The Adapter and Disposable Cones should be used for cohesive material and material where the DCP advances less than 1/2" per blow (CBR >18%). Attach the disposable cone to the adapter by applying pressure and rotating the cone. This will ensure proper seating and extend the life of the o-ring.

3.2.3 *Drive Rod (30", 37 3/4", or 48")-* Slide the Drive Rod into the anvil, insert the Quick-Connect Pin and retainer clip. Treat the drive rod with a light film of oil to minimize skin friction. This is especially important in cohesive soils.

3.2.4 *Drive Rod (12") with 12" or 24" Extension-* **Use only for material where DCP advances more than 1" per blow (CBR < 8%) and always use Disposable Cones.** Screw one 12" or 24" Extension Rod into the 12" Drive Rod and tighten with wrenches. Reassemble DCP hammer assembly and restart the test. The test can be conducted to a depth of 6 feet by adding additional Extensions Rods in a similar manner. If you are using the US Army Corps of Engineers Excel template we provide to reduce your data, it will be necessary to book each 22" segment of the test in a separate file as this template cannot be modified. You may wish to use the equations provided in paragraph 4.1 to make your own template.

3.2.5 *Adding 12" or 24" Extensions-* After the 12" Drive Rod and 24" Extension have been advanced, disconnect the Drive Rod from the anvil and the Extension Rod. Screw the second Extension Rod into the rod in the ground and the Drive Rod using wrenches. Reassemble DCP hammer assembly and restart the test. The test can be conducted to a depth of 6 feet by adding the Extensions in a similar manner. If you are using the Excel template we provide from the US Army Corps of Engineers to reduce your data, it will be necessary to book each 22" segment of the test in a separate file as this template cannot be modified. You may wish to use the equations provided in paragraph 4.1 to make your own template.

3.3 Testing Sequence

3.3.1 *Dropping the Hammer-* Hold the DCP device in a vertical position. Raise the Hammer until it touches, but does not impact, the handle. Allow the Hammer to fall freely and impact the anvil coupler assembly. Record the number of blows and corresponding penetration as described in paragraph 3.6.

3.3.2 *Depth of Penetration-* The depth of penetration will vary with application. For typical highway applications, a penetration of less than 692 mm (27 1/4 in) will generally be adequate. In soft soil, the DCP may be advanced to 6 feet (See PROCEDURES para 3.2.4 and 3.2.5).

7.2.3 *Extraction-* Following completion of the test, extract the device by driving the hammer upward against the handle. **Use a smooth upward movement and do not throw the hammer against the handle.**

7.3 Caution

- **DO NOT drop the hammer after refusal.**
- **DO NOT throw the hammer upwards.**
- **DO NOT rock the DCP side to side or forward and back in an attempt to loosen it from the ground.**

7.4 Use of Disposable Cones

7.4.1 The adapter and disposable cones should be used for cohesive material and material where the DCP advances less than 1/2" per blow (CBR > 18%). Attach the disposable cone to the adapter by applying pressure and rotating the cone. This will ensure proper seating and extend the life of the o-ring.

7.5 Initial Reading

7.5.1 *Testing a surface layer-* Hold the DCP vertically with the top of the widest part of the tip flush with the surface of the material to be tested.

7. PROCEDURES

7.1 Equipment Check

7.1.1 Before beginning a test, check to ensure the Drive Rod is straight by rolling the rod on a flat surface.

NOTE: The Drive Rod may bend if driven beyond refusal (see para 3.3.3).

7.1.2 The Hardened Point must be checked to ensure the 3 mm flat is discernible. The flat area will become rounded after about 250 tests and the hardened point should be replaced. Rarely, if ever, does the Hardened Point wear to the extent that the diameter fails to meet specifications (see para 2.2).

7.2 Testing Sequence

7.2.1 *Dropping the Hammer-* Hold the DCP device in a vertical position. Raise the Hammer until it touches, but does not impact, the handle. Allow the Hammer to fall freely and impact the anvil coupler assembly. Count the number of blows for corresponding penetration for each 2" increment on the drive rod. Use Tables 3, 4, and 5 for the correlation, the blow count, and the bearing capacity in PSF (pounds per square foot).

7.2.2 *Refusal-* The presence of aggregates > 2" or rock strata will either stop further penetration or deflect the drive rod. If, after 3 blows, the device has not advanced more than 0.08 in (2 mm) or the handle has deflected more than 3 in (75 mm) from the vertical position, stop the test and move the device to another test location. **Continuing to drop the hammer will damage the instrument.** The new test location should be a minimum of 12 in (300 mm) from the prior location to minimize test error caused by disturbance of the material.

3.3.3 *Refusal-* The presence of aggregates > 2" or rock strata will either stop further penetration or deflect the drive rod. If, after 3 blows, the device has not advanced more than 0.08 in (2 mm) or the handle has deflected more than 3 in (75 mm) from the vertical position, stop the test and move the device to another test location. **Continuing to drop the hammer will damage the instrument.** The new test location should be a minimum of 12 in (300 mm) from the prior location to minimize test error caused by disturbance of the material.

3.3.4 *Extraction-* Following completion of the test, extract the device by driving the hammer upward against the handle. **Use a smooth upward movement and do not throw the hammer against the handle.**

3.4 Caution

- **DO NOT drop the hammer after refusal.**
- **DO NOT throw the hammer upwards.**
- **DO NOT rock the DCP side to side or forward and backward in an attempt to loosen it from the ground.**

3.5 Initial Reading

3.5.1 *Testing a surface layer-* Hold the DCP vertically with the top of the widest part of the tip flush with the surface of the material to be tested. Take an initial reading from the Vertical Scale, measuring the distance to the nearest 1 mm (0.04 in).

3.5.2 *Testing below a bound layer-* When testing materials underlying a bound layer, a rotary hammer drill or coring apparatus meeting the requirements given in paragraph 2.4 is used to provide an access hole to the layer to be tested. Wet coring requires that coring fluid be removed immediately and the DCP test be performed as soon as possible. The coring fluid must not be allowed to soak into or penetrate the material to be tested. A wet/dry vacuum or suitable alternative is used after completion of drilling or coring to remove loose material and fluid from the access hole before testing. To minimize the extent of the disturbance from the rotary hammer, drilling should not be taken completely through the bound layer, but stopped short by about 10 to 20 mm. The DCP is then used to penetrate the bottom portion of the bound layer. This can be a repetitive process between drilling and doing DCP tests to determine the thickness of the layer.

3.5.3 *Testing pavement with thin seals* — For pavements with thin seals, the tip is advanced through the seal until the top of the widest part of the tip is flush with the layer to be tested.

3.5.4 *Once the layer to be tested has been reached-* A reference reading is taken with the cone zero point at the top of that layer and the thickness of the layer(s) cored through recorded. This reference reading is the point from which the subsequent penetration is measured.

3.6 Recording Methods

3.6.1 *Two person, traditional method (Figure 6A)-* When many tests are to be taken, it is best to have two people operating the DCP and recording the data. The recorder reads the scale at the top of the attachment or holds the Vertical Scale to the bottom of the widest part of the hammer and measures/records the cumulative penetration for the number of blows in a set. The set is the number of blows it takes to advance the DCP about 2 in (50 mm). The data is recorded on the DCP data sheet.

3.6.2 *One person with Vertical Scale (Figure 6B)-* Apply blue removable tape along the side of the Vertical Scale adjacent to the mm markings. Insert the Vertical Scale through the Upper Attachment and into the Foot. At the end of each set, the operator marks the position of the top edge of the Upper Attachment by drawing a line along it on the blue tape, and writes the number of blows required next to the line. After the test, the operator enters the

6. DESCRIPTION

6.1 The KESSLER DCP consists of an upper assembly with a Single Mass Hammer, a Drive Rod and a tip. The upper rod, drive rod, handle and anvil are stainless steel. The Drive Rod is held in place with a Quick-Connect Pin (Fig.3) through the anvil. The tip consists of an Adapter and Disposable Cone (Fig.4) or reusable Hardened Point (Fig.5). The DCP hammer is constructed of steel. The Hardened Points and the Adapters for the Disposable cones are heat treated then plated. The Disposable cones are plated steel.

6.2 The instrument is manufactured to the following specifications:

(1) Hammer weight measurement of 10.1lb (4.6Kg). Tolerance is 0.022lb (0.010K).
(2) Hammer weight measurement of 17.6 lb (8kg) tolerance is 0.022lb (0.010kg).
(3) Drop of hammer measurement of 22.6in (575mm). Tolerance is 0.039in (1.0mm).
(4) Tip included angle measurement of 60 degrees; tolerance is 1 degree.
(5) Tip base diameter measurement of 0.790 in (20 mm); tolerance is 0.010 in (0.25 mm).

5. APPLICATION

5.1 This application describes measurement of the penetration rate of the KESSLER DCP (Dynamic Cone Penetrometer) with a Single-Mass Hammer and quick-connect Drive Rod in field soil testing **without a Vertical Scale.**

5.2 This procedure is used to assess the in place strength of undisturbed soil and/or compacted materials. The penetration rate can be used to estimate CBR (California Bearing Ratio), shear strength of strata, and thickness of strata. It is ideal for horizontal construction applications, such as shallow foundations and pavement shoulders. Typically it is used to assess material properties to a depth of 36 in (914 mm) below the surface. With extensions the driving rod can be advanced to 6 ft (2 m).

5.3 The operator drives the DCP tip into soil by lifting the sliding hammer to the handle then releasing it. The total number of blows for a given depth(i.e. 2”, 4”, or 6”) is recorded. This blow count is then used to estimate the *in situ* shear strength or CBR from an appropriate correlation chart.

5.4 The Single Mass DCP can be used to estimate the strength characteristics of fine and grained soils, granular construction materials and weak stabilized or modified materials. It should not be used in highly stabilized or cemented materials or for granular materials containing aggregates greater than 2 in (50 mm).

Figure 6A–Two person, traditional method
One person operates DCP while the other person records penetration rate

Figure 6B–One person
One person operates DCP, then marks the tape on the Vertical Scale.

cumulative penetration and number of blows between marks on a DCP data sheet or in the Excel template.

3.6.4 *Magnetic Ruler (Figure 7)-* The optional Magnetic Ruler is a battery-operated AAA (Qty. 6), data-collection device for the Dynamic Cone Penetrometer (DCP). It displays depth, blows, mm/blow, cumulative mm/blow , and cumulative blow/inch in SI and English. The correlations are CBR (California bearing ratio) in %; Bearing capacity in Kips per square foot, and unconfined compression test in %. A flash drive records the data, information entered by the operator, and date and time for each test via a waterproof USB port.

3.7 Data Recording

A form like the one shown in Figure 8 is suggested for data recording. The recorder enters the header information before the test.

(1) The actual test data is recorded in column 1 (Number of Blows) and column 2 (Cumulative Penetration in mm); if the moisture content is available, it is entered in column 8.

(2) When testing a subsurface layer through a drilled or cored access hole, the first reading corresponds to the referenced reading at the top of the layer to be tested.

(3) The number of blows between readings may be varied depending on the resistance of the material. Normally readings will be taken approximately every 50 mm (2”), i.e. 1 blow for soft material, 5 blows for “normal” materials and 10 blows for very resistive materials.

(4) The tip should be advanced a minimum of 25 mm (1.0 in) between readings. The penetration to the nearest 1 mm (0.04 in) corresponding to the specific number of blows is recorded. A reading is taken immediately when the material properties or rate of advance change significantly.

PART II

DCP Without Vertical Scale

Table 1–Tabulated Correlation of CBR versus DCP Index[3]

DCP Index mm/blow	CBR %		DCP Index mm/blow	CBR %		DCP Index mm/blow	CBR %
<3	100		39	4.8		69-71	2.5
3	80		40	4.7		72-74	2.4
4	60		41	4.6		75-77	2.3
5	50		42	4.4		78-80	2.2
6	40		43	4.3		81-83	2.1
7	35		44	4.2		84-87	2.0
8	30		45	4.1		88-91	1.9
9	25		46	4.0		92-96	1.8
10-11	20		47	3.9		97-101	1.7
12	18		48	3.8		102-107	1.6
13	16		49-50	3.7		108-114	1.5
14	15		51	3.6		115-121	1.4
15	14		52	3.5		122-130	1.3
16	13		53-54	3.4		131-140	1.2
17	12		55	3.3		141-152	1.1
18-19	11		56-57	3.2		153-166	1.0
20-21	10		58	3.1		166-183	0.9
22-23	9		59-60	3.0		184-205	0.8
24-26	8		61-62	2.9		206-233	0.7
27-29	7		63-64	2.8		234-271	0.6
30-34	6		65-66	2.7		272-324	0.5
35-38	5		67-68	2.6		>324	>0.5

7[3] **Webster, S.L., Brown, R.W., Porter, J.R. (April 1994)**, Force Projection Site Evaluation Using the Electric Core Protection (ECP) and the Dynamic Cone Penetrometer (DCP), Technical Report No. GL-94-17, Air Force Civil Engineering Support Agency, U.S. Air Force, Tyndall Air Force Base, Florida

Figure 7–Magnetic Ruler

4. CORRELATIONS

4.1 The CBR may be estimated using the DCP index (column 6 on the DCP Data Sheet) and Table 1 for each set of readings. First, the DCP index is computed for the respective penetration between readings. The penetration per blow is then used to estimate *in situ* CBR or shear strength using the appropriate correlation for the reference. For example, the correlation of penetration per blow (DCP) in Table 1 is derived from the equation **$CBR = 292 / PR^{1.12}$** recommended by the US Army Corps of Engineers. This equation is used for all soils except for CL soils below CBR 10% and CH soils. For these soils, the following equations are recommended by the US Army Corps of Engineers, where PR is the DCP penetration rate in mm per blow: [3]

CL soils CBR < 10: $CBR = 1 / (0.017019 * PR)^2$

CH soils: $CBR = 1 / (0.002871 * PR)$

Selection of the appropriate correlation is a matter of professional judgment.

4.2 The Modulus of Rigidity M_R may be estimated using between 1300 to 1500 CBR.

4.3 If a distinct layering exists within the material tested, a change of slope on a graph of penetration/blow vs. depth will be observed for each layer. The exact interface is difficult to define because, in general, a transition zone exists between layers. The layer thickness can be defined by the intersection of the lines representing the average slope of adjacent layers. Once the layer thicknesses have been defined, the average penetration rate per layer is calculated.

4.4 The EXCEL™ template on the enclosed CD will graph the results of the test. (See instruction sheet included on CD). It will also plot a correlation of CBR to PSF (lbs/sq. ft).

Instruction for Data Recording Sheet:

(1) Number of hammer blows between test readings
(2) Cumulative penetration after each set of hammer blows
(3) Difference in cumulative penetration (2) between readings
(4) (3) divided by (1)
(5) Enter 1 for 17.6lb (8kg) hammer; 2 for 10.1 lb (4.6kg) hammer
(6) (4) x (5)
(7) From CBR verses DCP Index correlation
(8) % Moisture content when available

DCP DATA SHEET

Project: *Forest Service Road*
Location: *STA 30+50, 1 M RT of C/L*
Depth of zero point below: *0*
Material Classification: *GW/CL*
Pavement conditions: *Not applicable*

Date: *7 July 2005*
Personnel: *JLS & PAK*
Hammer Weight: *17.6lb (8kg)*
Weather: Overcast, 25°C, (72° F)
Water Table Depth: *Unknown*

	(1) Number of Blows	(2) Cumulative Penetration (mm)	(3) Penetration Between Reading (mm)	(4) Penetration per Blow (mm)	(5) Hammer Blow Factor	(6) DCP Index mm/blow	(7) CBR %	(8) Moisture %
1	0	0	--	--	--	--	--	
2	5	25	25	5.0	1	5.0	50	
3	5	55	30	6.0	1	6.0	40	
4	15	125	70	4.7	1	4.7	50	
5	10	175	50	5.0	1	5.0	50	
6	5	205	30	6.0	1	6.0	40	
7	5	230	25	5.0	1	5.0	50	
8	10	280	50	5.0	1	5.0	50	
9	5	310	30	6.0	1	6.0	40	
10	5	340	30	6.0	1	6.0	40	
11	5	375	35	7.0	1	7.0	35	
12	5	435	60	12.0	1	12.0	18	

Figure 8–DCP Data Sheet [2]

[2] **Webster, S.L., Grau, R.H. Williams, T.P., (May 1992),** Description and Application of Dual mass Dynamic Cone Penetrometer, Report GL-92-3, Department of the Army, Washington D.C., Pg. 19