vibratory roller handbook
with standardized terms and definitions
SECOND EDITION

Developed by the
Compaction and Paving Machinery Technical Committee (CPMTC)
Bituminous and Aggregate Equipment Bureau (BAEB)
of the Construction Industry Manufacturers Association
111 East Wisconsin Avenue • Milwaukee, Wisconsin 53202 • (414)272-0943
Acknowledgement

This Handbook was developed by the Compaction and Paving Machinery Technical Committee (CPMTC) of the Construction Industry Manufacturers Association (CIMA), with the support of the Bituminous and Aggregate Equipment Bureau (BAEB) – a product-oriented Bureau of CIMA. It represents the cooperative efforts and contributions of technical experts from the many member companies which manufacture, among a broad range of equipment for the bituminous industry, compaction equipment of all types.

A word about CIMA

CIMA is the U.S. based international trade group representing the producers of construction machinery and construction-related services used worldwide in the general construction, housing, roadbuilding, mining, energy and forestry fields. For more than 80 years, CIMA has acted as a forum for its member companies to discuss and act upon issues of industry-wide concern, including product safety, machine performance standards, government liaison, export and trade activity, parts and service information, training and the special concerns of the smaller and medium-sized manufacturer, among others. CIMA also produces the CONEXPO® International Construction Equipment Exposition, one of the world's largest machinery exhibitions.
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This Handbook on VIBRATORY ROLLERS is designed to serve the following purposes:

To reaffirm, promote and establish uniform, recognized and accepted terminology, and machine specifications for the guidance of manufacturers, distributors, buyers and users in comparing, specifying and presenting data relative to vibratory rollers;

To serve as a basis for common language and understanding among manufacturers, distributors, buyers and users in determining the basic types, features, operating characteristics and applications of vibratory rollers;

To provide means for the identification of common types of vibratory rollers;

To increase the knowledge of individuals involved with compaction and compaction machines, and to enhance their ability to communicate and carry out their responsibilities efficiently and effectively;

To provide useful text and reference material for code-writing agencies, regulatory agencies, engineers, marketing personnel, contractors, equipment operators, schools, students, and others interested in, or involved with, the field of compaction.
This Handbook provides standardized terminology pertaining to vibratory rollers and their operation, standardized parameters for designating the specifications and characteristics of vibratory rollers, and other information of general interest to those associated with, or interested in, vibratory rollers and their operation.

This Handbook is not intended to establish machine requirements nor to promote the acceptance or use of any specific type of compactor — vibratory or otherwise. It is likewise not intended to be an exhaustive treatise on the subject of vibratory rollers.

This Handbook covers ride-on, walk-behind and towed machines.

Excluded from coverage are all static rollers, and all vibratory plate and rammer compactors.

Also excluded from coverage in this Handbook are safety-related matters, which are covered in manufacturers' manuals, and in CIMA's *Roller Compactor Safety Manual*, one of a series of operator safety manuals developed and published by CIMA, covering various types of construction machines.
Vibratory compaction may seem to some of us to be a recent technological innovation. While vibratory compaction is relatively new, the theory and application of soil compaction is as old as recorded history itself.

In early civilization, soil compaction methods employed the dynamic forces of moving animals and men. The motion of a foot (or hoof) is similar in some respects to the motion of a padded drum.

With the Romans came the advancement of civilization and the art of road building. The Roman method of road construction was to first make a cut the width of the planned road, deep enough to hold the fill. The earth at the bottom of the cut was made more solid through the use of heavy rammers, and a foundation layer of stones was laid on this compacted base. This layer was then covered with a 9-inch layer of concrete. Next a 6-inch layer of fine concrete was laid, in which were set blocks of lava or other type of stone. This final course was then rolled, using a cylindrical stone pulled by an attached yoke (the first towed-type roller). Some sections of these Roman roads are still being used today.

With the fall of the Roman Empire, the art of road building declined. The construction of an 18th-century road in England consisted of men digging ditches along each side of the proposed road and throwing the excavated dirt into the middle of the road bed, hoping that passing vehicles would act as compactors. A sticky situation existed during heavy rain spells.

Around 1815 John London MacAdam, a Scottish engineer, introduced a paving technique which greatly advanced road building in England. MacAdam's method was to mix small pebbles with clay or rock dust. The surface was then troweled smooth and compacted. With the proper mixture this material became almost as hard as concrete.

In 1869 a new innovation from England, known as the steam roller, was tried in New York. This early type of smooth-wheel roller proved to be very effective in highway construction for nearly a century.

The photograph below shows a Chinese method of soil compaction which employed the theory of variable amplitude. It is reasonable to assume that this method is centuries old.
Various theories of, and testing methods for, soil compaction evolved in the 1920's, but it was not until 1933 that R. R. Proctor published his basic theories dealing with the effect of moisture content on compaction results. Proctor devised testing methods for determining the optimum moisture content, and also procedures for determining compaction in the field.

Vibratory compaction of soils was first employed in Germany in the early 1930's in connection with the construction of its highway system. The first type of vibratory compactor was the 1½-ton base plate unit, followed by a crawler type of compactor weighing about 25 tons, manufactured by the Losenhausen Company.

The first towed type of vibratory rollers for soil compaction in the United States was manufactured in the 1940's. Self-propelled designs followed in the late fifties. The growth in popularity of these vibratory rollers continued at a rather steady rate into the 1960's, when their popularity rose sharply. The latter sixties saw the introduction of a vibratory roller for compacting hot mix asphalt pavements. During the next few years a series of rapid advancements produced vibratory rollers which experienced outstanding success on both granular and cohesive soils, as well as on asphalts. Today, vibratory rollers are widely used and accepted for compacting asphalt pavements because they achieve the required densities faster and are thereby capable of increasing production. The large double drum vibratory rollers, which first appeared in 1969, provided even further production capabilities for the main line rolling of asphalt pavements.

Today many different types and variations of vibratory rollers are manufactured and used to meet widely varying soil and field conditions, from granular soils to asphaltic concrete.
vibratory compaction

Tests conducted around the world commercially, academically and on the job have shown the benefits of vibratory compaction for achieving density, depth penetration and economy of compaction. Both machine and material factors contribute to its success. Many such factors exist; they are interrelated; and each varies in effect and importance with differing material and working conditions.

A drum's static weight applies a compacting force; however, by inducing vibration of that drum, the compacting force is increased. The momentary, high cyclic forces of the vibrating drum overcome frictional and cohesive resistance of the material being compacted, facilitating greater density.

Machine factors which affect vibratory compaction efficiency include machine weight, drum weight and construction, sprung weight, machine suspension, vibratory frequency, amplitude, the vibration-inducing mechanism, and speed of travel.

Compaction effectiveness also depends greatly upon the material being compacted. Typical variables include the type of material moisture or asphalt content, lift thickness, temperature, and underlying support. In addition, the characteristics of the material being compacted change as the density increases.

Comparative rating of vibratory rollers

Due to the many variables mentioned above in achieving compaction performance, there is no known specification which indicates the overall effectiveness of a vibratory roller. The best comparative rating between vibratory rollers is the resulting density, surface smoothness and rate of production on a specific application.
**description of a vibratory roller**

A vibratory roller is a compactor having a drum* (roll or horizontal cylinder) used to densify (compact) soil, asphalt or other materials through the application of combined static and dynamic forces (weight and vibrations) to increase the load-bearing capacity of the surface.

The machine may have one or more drums, which may or may not be powered for propulsion. The machine may have drive members such as rubber tires in addition to the drums. The centrifugal force is normally produced by one or more rotating offcenter weights, which produce a cyclic movement of the drum. The amplitude and frequency of drum movements cover a wide range of values. The drum(s) and drive wheels may be smooth or may include projections designed for specific compaction purposes. These projections vary as to material, size and shape.

Vibratory rollers may be self-propelled or towed, rigid frame or articulated, and controlled by either a riding or walking operator, manually or remotely. See page 8 for representative types.

*Drum and roll are used interchangeably in this Handbook.*
representative types of vibratory rollers for soil and asphalt compaction

Smooth or multiple projection (padfoot, sheepsfoot or grid) drums

1 Single drum, ride-on (with one or more pneumatic tires)
   a. Articulated Frame
   b. Rigid Frame

2 Tandem, double drum, ride-on (One or both drums may vibrate)
   a. Single Articulated
   b. Double Articulated Steering
   c. Rigid Frame

3 Single drum, walk-behind

4 Double drum, walk-behind (One or both drums may vibrate)
   a. Articulated Frame
   b. Rigid Frame

5 Towed
basic machine specifications* recommended

for publication by manufacturers of vibratory rollers

Operating Weight (kilograms, pounds)
Shipping Weight (kilograms, pounds)
Drum Diameter (millimeters, inches)
Drum Width (millimeters, inches)
Number of Vibrating Drums
Overall Width (millimeters, inches)
Operating Height (millimeters, inches)
Overall Length (millimeters, inches)
Wheelbase (millimeters, inches)

Turning Radius at the outside edge of Drum(s) and Tires if wider than drum (meter, inches)
Static Weight at Drum(s) and at Tire(s) (kilograms, pounds)
Centrifugal Force at a Stated Frequency (kilonewton, pounds)
Vibrating Mass (kilograms, pounds)
Eccentric Moment (kilogram meters, inch pounds)
Frequency (hertz, VPM)
Nominal Amplitude (millimeters, inches)
Type of Engine

Net Intermittent Power at Installed Full Load Governed Speed per SAE J1349 (kilowatts, horsepower @ _____________ RPM)
Speed Forward and Reverse (kilometers per hour, miles per hour)
Fuel Capacity (liters, U.S. gallons)
Water Spray System Capacity (liters, U.S. gallons)
Curb Clearance (millimeters, inches)

Oscillating Angle from Pivot Center (+ degrees)
Tire Size and Ply rating

Additional Specifications for Padfoot Machines Only
Diameter Over Pads (millimeters, inches)
Pad Area (square millimeters, square inches)
Pad Height (millimeters, inches)
Number of Pads

Specifications NOT Recommended
Total Applied Force and all its derivatives
Centrifugal Force Described as Energy or with a time or travel distance factor (Example: tons per second)
Any equivalent rating of a vibratory roller to a static roller
Gradeability
Double Amplitude

NOTES: 1. When a vibratory roller has more than one vibrating drum, the weight and force specifications will be for each drum.
2. For compactors equipped with External (not inside the drum) vibrating mechanism, this must be clearly stated.
3. Specifications do not necessarily apply to all types of machines.
standard specifications label for vibratory rollers

VIBRATORY ROLLER SPECIFICATIONS

MANUFACTURERS NAME
Address
City, State, Zip

MODEL __________________ SERIAL NO. __________________

OPERATING WEIGHT __________________ kg __________________ lb

DRUM DIAMETER __________________ mm __________________ in

DRUM WIDTH __________________ mm __________________ in

NUMBER OF VIBRATING DRUMS __________________

CENTRIFUGAL FORCE PER VIBRATING DRUM __________________ kn @ __________________ Hz

__________________________________________ lb @ __________________ VPM

NOMINAL AMPLITUDE (RANGE) __________________ mm __________________ in

FREQUENCY (RANGE) __________________ Hz __________________ VPM

SAFETY FIRST:
Do not make modifications or add other than factory-authorized accessories to this machine.

Specifications are based upon terms and definitions established by the Bituminous and Aggregate Equipment Bureau (BAEB) and Compaction and Paving Machinery Technical Committee (CPMTC) of the Construction Industry Manufacturers Association (CIMA). 111 E. Wisconsin Ave., Milwaukee, Wisconsin 53202 USA., Phone 414-272-0943

Note: This is a suggested format for companies to use when producing specifications labels which may be applied to their equipment.
# Vibratory Roller Terms & Definitions

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<tr>
<th>Term</th>
<th>Symbol</th>
<th>Definition</th>
<th>SI Metric Units</th>
<th>English Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amplitude, Actual Double</strong></td>
<td></td>
<td>Double amplitude as measured under operating conditions. This will vary with the conditions of the material being densified and the vibration frequency.</td>
<td>Millimeters (mm)</td>
<td>Inches (in.)</td>
</tr>
<tr>
<td><strong>Amplitude, Double</strong></td>
<td>DA</td>
<td>The total peak to peak vertical movement per complete vibrating cycle of the drum in a freely suspended condition. Double Amplitude is twice the Nominal Amplitude. Note: This term is not recommended for specifications.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Amplitude, Nominal**        | A      | Nominal amplitude is calculated by using the following formula: 
  
  \[ A = \frac{m \times r}{Mv} \quad \text{or} \quad A = \frac{w \times r}{Mv \times g} \]  

  (SI metric units) (English Units)  

  The eccentric moment \((m \times r)\) or \((w \times r)\) divided by the vibrating mass \((Mv)\) in SI Units or \(Mv \times g\) in English Units. | Millimeters (mm) | Inches (in.) |
| **Amplitude, Variable**       |        | Nominal Amplitude change accomplished by varying the eccentric moment. This is independent of frequency.                                         |                 |              |
vibratory roller terms & definitions (continued)

<table>
<thead>
<tr>
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<th>English Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BALLAST WEIGHT</td>
<td></td>
<td>Material added to increase the weight of the machine.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CENTRIFUGAL FORCE</td>
<td>$F_c$</td>
<td>The force generated by the vibration-inducing mechanisms at a stated frequency. To compute centrifugal force: (SI Metric Units) $F_c = 3.948 \times 10^{-2} \ (m \times r) \times f^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(English Units) $F_c = 2.840 \times 10^{-5}\ (w \times r) \times f^2$</td>
<td>Kilonewton (kN)</td>
<td>Pounds (lb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: In calculations, it is customary for the sake of simplicity to assume that r (in the formula) is measured from the true bearing center.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPACTOR</td>
<td></td>
<td>A machine designed and used specifically to compact materials. It densifies material through the application of static force or dynamic force combined with static force.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRUM</td>
<td></td>
<td>A rotating cylindrical member used to transmit compaction forces to soil or other surface materials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DYNAMIC FORCE APPLIED</td>
<td></td>
<td>The vectorial resolution of all the generated forces and the static forces at the interface of the drum and the material being compacted.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: The Dynamic force applied varies with the types and conditions of the material being compacted. Therefore this term is not recommended to be used in rating compactors.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECCENTRIC MOMENT</td>
<td>$(m \times r)$</td>
<td>The product of the unbalanced mass $(m)$/unbalanced weight $(w)$ times the distance $(r)$ from the center of gravity of the unbalanced mass to the bearing center.</td>
<td>Kilogram-Millimeter (kg-mm)</td>
<td>Pounds-Inch (lb-in)</td>
</tr>
<tr>
<td></td>
<td>$(w \times r)$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**

- **CENTER OF GRAVITY**
- **CENTER OF ROTATION**

**Equations:**

- **UNBALANCED MASS** = $m$
- **UNBALANCED WEIGHT** = $w$
- **DISTANCE** = $r$
- **ECCENTRIC MOMENT** = $m \times r$ (SI Units)
- **ECCENTRIC MOMENT** = $w \times r$ (English Units)
# Vibratory Roller Terms & Definitions (continued)

<table>
<thead>
<tr>
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<th>English Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FREQUENCY</strong></td>
<td>Hertz</td>
<td>The number of complete cycles of the vibrating mechanism per unit time.</td>
<td>Hertz (Hz)</td>
<td>Vibrations per minute (VPM)</td>
</tr>
<tr>
<td><strong>GRADEABILITY</strong></td>
<td></td>
<td>To be consistent with SAE and ISO it is recommended that this term not be used in the machine specifications. The surface and operating conditions can change the actual gradeability of the compactor compared to the theoretical calculated numbers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LINEAR CENTRIFUGAL FORCE</strong></td>
<td></td>
<td>The centrifugal force generated per drum divided by the drum width.</td>
<td>Kilonewton Per Millimeter (kN/mm)</td>
<td>Pounds Per Linear Inch (PLI)</td>
</tr>
<tr>
<td><strong>LINEAR STATIC FORCE</strong></td>
<td></td>
<td>The static weight divided by the drum width.</td>
<td>Kilograms Per Millimeter (kg/mm)</td>
<td>Pounds Per Linear Inch (PLI)</td>
</tr>
<tr>
<td><strong>NON-VIBRATING WEIGHT</strong></td>
<td></td>
<td>The static weight measured at the drum(s) on the ground, minus the vibrating weight.</td>
<td>Kilograms (kg)</td>
<td>Pounds (lb)</td>
</tr>
<tr>
<td><strong>OPERATING WEIGHT</strong></td>
<td></td>
<td>The gross machine weight with full mechanical operating systems, a full tank of fuel, one-half sprinkler tank of water, if so equipped, and a 75 kg (165 lb.) operator. If the operating weight includes a ballast, the location, type(s), and weight of the ballast should be so designated.</td>
<td>Kilograms (kg)</td>
<td>Pounds (lb)</td>
</tr>
<tr>
<td><strong>PASS</strong></td>
<td></td>
<td>A one-way trip or passage of the machine. A round trip in the same path is two passes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RESONANT FREQUENCY</strong></td>
<td></td>
<td>The actual frequency at which the combination of the drum and material exhibits the greatest amplitude; that is when the generated frequency coincides with natural frequency of the material being compacted.</td>
<td>Hertz (Hz)</td>
<td>Vibrations per Minute (VPM)</td>
</tr>
<tr>
<td><strong>ROLL</strong></td>
<td></td>
<td>See drum.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SHIPPING WEIGHT</strong></td>
<td></td>
<td>The weight of the machine as shipped by the manufacturer.</td>
<td>Kilograms (kg)</td>
<td>Pounds (lb)</td>
</tr>
<tr>
<td><strong>SPRUNG WEIGHT</strong></td>
<td></td>
<td>See non-vibrating weight (mass).</td>
<td>Kilograms (kg)</td>
<td>Pounds (lb)</td>
</tr>
<tr>
<td><strong>STATIC WEIGHT</strong></td>
<td></td>
<td>That portion of the operating weight (mass) exerted on the ground at the drum(s).</td>
<td>Kilograms (kg)</td>
<td>Pounds (lb)</td>
</tr>
</tbody>
</table>
vibratory roller terms & definitions (continued)

<table>
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<th>English Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL APPLIED FORCE</td>
<td></td>
<td>This term is not recommended for rating rollers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNSPRUNG MASS</td>
<td></td>
<td>See vibrating mass.</td>
<td>Kilograms (kg)</td>
<td>Pounds (lb)</td>
</tr>
<tr>
<td>VIBRATING MASS</td>
<td>Mv</td>
<td>The mass of all the intentionally vibrated parts at each drum.</td>
<td>Kilograms (kg)</td>
<td>Pounds (lb)</td>
</tr>
<tr>
<td>VIBRATORY ROLLER</td>
<td></td>
<td>A compactor which has one or more of its drums intentionally vibrated.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>(See page 7 for description)</td>
<td></td>
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</tr>
</tbody>
</table>

NOTE: For weight, kilograms have been used instead of SI Metric Units of Kilogram force or Newton to recognize common usage.