EARTHMOVING PLAN

Yamazaki Construction Co., Ltd.
1. 仕様書の作成

2. 仕様書の作成

3. 仕様書の作成

4. 仕様書の作成

5. 仕様書の作成

6. 仕様書の作成

7. 仕様書の作成

8. 仕様書の作成

9. 仕様書の作成
1. Construction Mechanization

Since some form of equipment is used in every operation in present construction work, work and equipment have a very close relationship. The meaning of construction mechanization is condensed into the following.

1. To realize the works beyond human power
2. To decrease the cost
3. To shorten the term
4. To uniform the quality of structure

As mentioned above, in construction work the advantages of mechanization are great, but on the other hand, mistakes in control would result in big losses. Therefore, it is necessary for site engineer to have knowledge and experience, and to use a method of control suited to the site.

Advantages of mechanization are:
1. Larger scale operations possible
2. Reduced work time
3. Uniformity and improvement
4. Making larger operating unit
5. Reduced manpower
6. Relief from heavy manual or exhausting work
7. Improved operating safety

But disadvantages of mechanization are:
1. Large capital needed for obtaining equipments
2. Increased management work for equipments
3. Problems with training and keeping operations
4. Effort needed to keep up efficient control of mechanization

It needs optimum selection and management of equipments to succeed in the construction mechanization.
2. Framing of Earthmoving Execution Plan

In general case, procedure of earthmoving work plan is investigated outline of whole process to complete within the term at first, and finished by adjusting the rough plan according to conditions at several process.

Earthmoving execution plan is carried out by following procedure in general in case of road construction.

‡A Understanding of specifications and site condition according to design data and surveying of the field.

‡B Setting up rational distribution of soil by considering cutting area, filling area and quantity, etc.

‡C Deciding optimum working lot by considering distribution of soil and relation with other structures and works.

‡D Checking the relation in connection with each major working process.

‡C Selecting the work method and the equipment in major working process. Estimating the approximate cost of work and comparing with the cost of other methods when selecting the work method.

‡E Estimating the work period and summing up to them in each process. As next stage, adjusting several periods in order to accept within the term, and finally completing the whole process.

‡D Adding sub working process and attached working process to major process, and making whole plan.

‡E Reviewing, correcting or adjusting about the detail of the whole plan and finishing the plan completely.

‡G Making the schedule chart of work plan to apply the working control.

Yamazaki 4
3. Selection of Earthmoving Equipment

Earthmoving are usually many alternatives of construction method. It has to consider many factors which are soil condition, working area, hauling distance, quantity, construction term, weather, etc. when selecting earthmoving equipment.

3.1 Kinds of Work

<table>
<thead>
<tr>
<th>Kinds of Work</th>
<th>Equipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearing</td>
<td>Bulldozer, Rakedozer, Backhoe, Chipper</td>
</tr>
<tr>
<td>Excavating</td>
<td>Shovel (Backhoe, Dragline, Clamshell)</td>
</tr>
<tr>
<td>Loading</td>
<td>Bulldozer, Ripper, Rock breaker</td>
</tr>
<tr>
<td>Excavating / Loading</td>
<td>Wheel Loader, Track Loader</td>
</tr>
<tr>
<td>Excavating / Hauling</td>
<td>Loading shovel (Front shovel)</td>
</tr>
<tr>
<td>Hauling</td>
<td>Power shovel (Backhoe, Dragline, Clamshell)</td>
</tr>
<tr>
<td>Spreading / Grading</td>
<td>BWE (Bucket Wheel Excavator)</td>
</tr>
<tr>
<td>Compacting.</td>
<td>Bulldozer, Scrapedozer, Scraper</td>
</tr>
<tr>
<td>Trenching</td>
<td>Dump truck (Rigid, Articulated), Wagon, Conveyer</td>
</tr>
<tr>
<td>Maintaining macadam road</td>
<td>Clowler dump</td>
</tr>
<tr>
<td>Slant finishing</td>
<td>Bulldozer, Wheel dozer, Motor grader</td>
</tr>
<tr>
<td>Rock Braking</td>
<td>Tire roller, Steel roller, Vibration roller, Tamping roller, Vibration compactor, Tamper, Bulldozer</td>
</tr>
<tr>
<td>Trencher</td>
<td>Trencher, Backhoe</td>
</tr>
<tr>
<td>Motor grader</td>
<td>Backhoe, Motor grader</td>
</tr>
<tr>
<td>Drill, Breaker, Spliter</td>
<td>Drill, Breaker, Spliter</td>
</tr>
<tr>
<td>Chipper</td>
<td>Chipper</td>
</tr>
</tbody>
</table>

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3.2 The effect to use popularized or standard type equipments

In general, it can consider that the equipment having larger size assures a lower cost of working. However it often happens that use of large size equipment does not always its ability to be fully demonstrated. Because it requires a higher cost of transporting and disassembles/assemble, to increase the loss due to repairs and suspension, thus it results to be uneconomically. It can be said concerned with special made equipment in the same reason.

Therefore generally speaking, the popularized or standard type equipment is mostly advantageous from technical and economical viewpoint.

The effect to use popularized or standard type equipment are following.

1) They may be obtained easily and quickly.
2) They can be used economically on more than one project,
3) Repair parts for them may be obtained quickly and economically.
4) When they are no more needed, they can be usually disposed easily and at a favorable price.

### Table-2 Popularized or standard type equipments in Japan

<table>
<thead>
<tr>
<th>Kinds of Equipment</th>
<th>Popularized or standard type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulldozer</td>
<td></td>
</tr>
<tr>
<td>Bulldozer with ripper</td>
<td></td>
</tr>
<tr>
<td>Scraperdozer</td>
<td></td>
</tr>
<tr>
<td>Tractor-pulled scraper</td>
<td></td>
</tr>
<tr>
<td>Motor scraper</td>
<td></td>
</tr>
<tr>
<td>Backhoe (hydraulic type)</td>
<td></td>
</tr>
<tr>
<td>Clamshell</td>
<td></td>
</tr>
<tr>
<td>Loader</td>
<td></td>
</tr>
<tr>
<td>Dump truck</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Equipment</th>
<th>Normal</th>
<th>Swamp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7~27 (ton)</td>
<td>7~27 (ton)</td>
</tr>
<tr>
<td></td>
<td>27~103 (ton)</td>
<td>27~103 (ton)</td>
</tr>
<tr>
<td></td>
<td>8.0 (m³)</td>
<td>8.0 (m³)</td>
</tr>
<tr>
<td></td>
<td>9, 15, 23 (m³)</td>
<td>9, 15, 23 (m³)</td>
</tr>
<tr>
<td></td>
<td>24 (m³)</td>
<td>24~34 (m³)</td>
</tr>
<tr>
<td></td>
<td>0.01~11 (m³)</td>
<td>0.01~11 (m³)</td>
</tr>
<tr>
<td></td>
<td>0.3, 0.8 (m³)</td>
<td>0.3, 0.8 (m³)</td>
</tr>
<tr>
<td></td>
<td>0.4~3 (m³)</td>
<td>0.4~12 (m³)</td>
</tr>
<tr>
<td></td>
<td>4~15 (ton)</td>
<td>4~15 (ton)</td>
</tr>
<tr>
<td></td>
<td>20~90 (ton)</td>
<td>20~90 (ton)</td>
</tr>
</tbody>
</table>

Scrapedozer SR280

Yamazaki
Excavation
Load
Haul
Compaction

Fig. 1 Earthmoving Flow

Hard Rock Soft Rock Soil

Tractor drawn Scraper
Motor Scrapers
Wheel Loader
Scrapdozer
Track-type Loader
Hydraulic Excavators
Clamshell
Ripper

Fig. 2 Co-Operation

Table 3: Kind of Work & Typical Co-Operation Equipments

<table>
<thead>
<tr>
<th>Work</th>
<th>Typical Co-Operation Equipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavating / Loading / Hauling</td>
<td>Bulldozer + Loading equipment + Dump Truck</td>
</tr>
<tr>
<td>Spreading / Compacting</td>
<td>Spreading equipment + Compact equipment</td>
</tr>
<tr>
<td>Loading / Hauling / Spreading</td>
<td>Scraper + (Pusher)</td>
</tr>
</tbody>
</table>

4. Cost of Earthmoving

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The cost of earthmoving is generally shown by cost per working volume as the following formula:

\[ C = \frac{P}{Q} \]

Where
- \( C \) : Cost of earthmoving (yen/\( m^3 \))
- \( P \) : Cost of equipment (yen/h)
- \( Q \) : Working ability of equipment (\( m^3/h \))

The cost of equipment is consistent with the cost of earthmoving in various cases. In the case of earthmoving for road construction, the cost of equipment consists of the following:

- Owning Cost
- Depreciation Cost
- Maintenance and Repair Costs
- Tax, Insurance, Storage, etc.

- Operating Cost
- Operator Costs
- Fuel and Lubricating Costs
- Consuming Parts Costs, etc.
- Others
- Set up / Breakdown Costs
- Transporting Costs, etc.

For example, the cost of equipment for a specific project might include:

- The initial purchase cost
- Annual depreciation
- Regular maintenance and repair
- Fuel and lubrication expenses
- Replacement parts
- Setup and breakdown costs
- Transportation costs

A detailed analysis of these costs is crucial for an accurate estimation of the total earthmoving cost.
5. Estimate Production

5.1 Working Ability of Equipment

The feature of earthmoving is mainly consist of repeat or gathering of simple works. To give an example, loading work of power shovel is consist of excavating, turn, loading to track and return for one cycle.

The working ability, generally shown by working volume per hour and is expressed as the following basic formula.

\[ Q = q \cdot n \cdot f \cdot E \]

\[ = \frac{60 \cdot q \cdot f \cdot E}{Cm} \]

where

- \( Q \) : Working volume per hour (m³/h)
- \( q \) : Payload: heaped capacity (m³/trip)
- \( n \) : Number of cycle (trip/h)
- \( f \) : Earth volume conversion factor
- \( E \) : Efficiency factor
- \( Cm \) : Cycle time (min)

\( E \) is considered to divide \( E_1 \) and \( E_2 \) as following, but it is practically difficult to distinguish between \( E_1 \) and \( E_2 \).

\[ E_1 = \frac{T_w}{T_w + T_o} \]

where

- \( E_1 \) : Working time rate
- \( T_w \) : Real Working Time
- \( T_o \) : Traveling Time + Idling Time + Waiting Time in Working (within about 10 min) + others
- \( E_1 + T_o \) : Operating Time

\( E_1 \) depends on earthmoving method, co-operating equipment, working condition, hauling distance, maintenance condition of equipment, etc. \( E_1 \approx 0.6 \sim 0.9 \)

\( E_2 \) is working ability rate that depends on soil condition, weather condition, selection of equipments, operator ability, etc. \( E_2 \approx 0.5 \sim 0.85 \)
\[ Q = \frac{60 \cdot q \cdot f \cdot E}{Cm} \]
\[ = \frac{3600 \times q \times f \times E}{2.2 \times \ell + 15} \]

where \( \ell \) : 載重距離 \\

\[ Q = \frac{60 \cdot q \cdot f \cdot E}{Cm} \]
\[ = \frac{60 \times q \times f \times E}{1.7 + 0.026 \times \ell} \]

\[ Q = \frac{60 \cdot q \cdot f \cdot E}{Cm} \]
\[ = \frac{60 \times q \times f \times E}{0.06 \times \frac{\ell_1}{V_1} + 0.06 \times \frac{\ell_2}{V_2} + t_0} \]

where \( \ell_1 \) : 進距離 \\
(1) Bulldozer

\( \ell_2 \) : 退距離 \\
(2) Tractor drawn Scraper

\( V_1 \) : 進速度 \\
(3) Motor Scraper, Dump Truck

\( V_2 \) : 退速度 \\
(4) Loader, Backhoe

\( t_0 \) : 停止時間

\[ Q = \frac{60 \cdot q \cdot f \cdot E}{Cm} \]
\[ = \frac{3600 \times q_h \times f \times E}{Cm \times n} \]

where \( q_h \) : 載重容量

\( n \) : 載重率
\[ Q = \frac{S \cdot 1000 \cdot W \cdot h \cdot E}{P} \times f \]

Where:
- \( Q \): Compacted Production per 60 minute hour (m\(^3\)/h)
- \( S \): Compacting Speed (km/h)
- \( W \): Compacting Width
- \( h \): Compacted lift Thickness
- \( E \): Earth volume conversion factor
- \( P \): Number of Passes required (trip/layer)
- \( f \): Earth density conversion factor

Working capacity per day (QD) and during term (Qy) are shown as following.

\[ QD = Q \times TD \]

Where:
- \( QD \): Working Ability per day (m\(^3\)/d)
- \( TD \): Operating Time per day (h/d)

(TD \( \leq 7 \) h/d for earthmoving Equipment)

Operating Time

<table>
<thead>
<tr>
<th>Operator working Time</th>
<th>Other Operating time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Working Time</td>
<td>Checking, Investment</td>
</tr>
<tr>
<td>Pause</td>
<td>Recess, Others</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ Qy = QD \times D \]

Where:
- \( Qy \): Working Ability during term (m\(^3\))
- \( D \): Operating Day during term (day)

\( D \) depends on rainfall, soil

Required term (DT) for the term

\[ DT = D + (\text{holiday}) + (\text{pause day by rainfall}) + (\text{pause day by after rainfall}) + (\text{pause day for repair equipment, prepare and settle, etc.}) \]
Volume Change Characteristics of Soils

Following are the three principal states in which earthmoving material may exist:

- **Natural (in-place)**: Soil in its natural state. A unit volume is referred to as a bank cubic meter (Bm³).
- **Loose**: Soil after excavation or loading. A unit volume is referred to as a loose cubic meter (Lm³).
- **Compacted**: Soil after compaction. A unit volume is referred to as a compacted cubic meter (Cm³).

**Table 4: Conversion factor**

<table>
<thead>
<tr>
<th>State</th>
<th>Natural (in-place)</th>
<th>Excavated</th>
<th>Compacted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural (in-place)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excavated</td>
<td>1/L</td>
<td>1/C</td>
<td></td>
</tr>
<tr>
<td>Compacted</td>
<td>L</td>
<td>L/C</td>
<td>1</td>
</tr>
</tbody>
</table>

**Fig. 3: Typical Volume change due to handling**

Yamazaki 12
### Table 5: Typical soil volume conversion factors

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Loose</th>
<th>Compacted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel &amp; Gravelly Soil</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Gravel</td>
<td>0.95</td>
<td>0.90</td>
</tr>
<tr>
<td>Sand &amp; Sandy Soil</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Cohesive Soil</td>
<td>1.30</td>
<td>1.25</td>
</tr>
<tr>
<td>Swampy Cohesive Soil</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Boulder</td>
<td>1.20</td>
<td>1.00</td>
</tr>
<tr>
<td>Soft Rock (I)</td>
<td>1.30</td>
<td>1.15</td>
</tr>
<tr>
<td>Soft Rock (II)</td>
<td>1.50</td>
<td>1.20</td>
</tr>
<tr>
<td>Medium Rock</td>
<td>1.60</td>
<td>1.25</td>
</tr>
<tr>
<td>Hard Rock (I)</td>
<td>1.65</td>
<td>1.40</td>
</tr>
<tr>
<td>Hard Rock (II)</td>
<td>1.70</td>
<td>1.50</td>
</tr>
</tbody>
</table>

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\[ L = \frac{\text{Loose volume}}{\text{Bank volume}} \quad C = \frac{\text{Compaction volume}}{\text{Bank volume}} \]

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#### 5.3 Fleet Production

In earthmoving, some co-working equipments are generally used depending on the work to be performed.

a) The working ability of the co-working equipments is determined by the equipment having the minimum working ability in them.

b) The working ability of each equipment should be well balanced.

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#### 5.4 Productivity of Combination Work by Oneself

Production of combination work by one equipment, which is for example ripping, and dozing work by one bulldozer is expressed by following formula.

\[ Q = \frac{Q_1 \times Q_2}{Q_1 + Q_2} \]

where:

- \( Q \): Production of combination work \((m^3/h)\)
- \( Q_1 \): Ripping ability \((m^3/h)\)
- \( Q_2 \): Dozing ability \((m^3/h)\)
6. Soil Condition

6.1 Trafficability

Trafficability refers to the evaluation of how much the ground can bear the traveling of equipment, and is especially important for the field of soft soil. Trafficability of soil is usually evaluated by cone index that is measured by using cone penetrometer.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cone index (kg/cm²)</th>
<th>Contact pressure of equipment (kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super swampdozer</td>
<td>More than 2</td>
<td>More than 3</td>
</tr>
<tr>
<td>Swampdozer</td>
<td>More than 3</td>
<td>More than 3</td>
</tr>
<tr>
<td>Bulldozer (21t class)</td>
<td>More than 5</td>
<td>More than 6</td>
</tr>
<tr>
<td>Scraperdozer</td>
<td>More than 6</td>
<td>More than 7</td>
</tr>
<tr>
<td>Bulldozer (32t class)</td>
<td>More than 7</td>
<td>More than 7</td>
</tr>
<tr>
<td>Tractor-pulled scraper</td>
<td>More than 10</td>
<td>More than 12</td>
</tr>
<tr>
<td>Motor Scraper</td>
<td>More than 10</td>
<td>More than 12</td>
</tr>
<tr>
<td>Dump Truck</td>
<td>More than 10</td>
<td>More than 12</td>
</tr>
</tbody>
</table>

\[ Qc = \frac{\text{mean resistance force (kg)}}{\text{base area of cone (3.24cm}^2\text{)}} \]
### Table 7: Kinds of soil and equipment

<table>
<thead>
<tr>
<th>Kinds of soil</th>
<th>Equipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand, Sandy soil</td>
<td>Wheel-type or Track-type tractor --- (loosened)</td>
</tr>
<tr>
<td>Clay, Cohesive soil</td>
<td>Power shovel, Bulldozer --- (fixed)</td>
</tr>
<tr>
<td>Soft rock</td>
<td>Power shovel</td>
</tr>
<tr>
<td>Hard rock</td>
<td>Bulldozer with ripper, Rock breaker</td>
</tr>
<tr>
<td></td>
<td>Large size bulldozer with ripper --- (after loosening with dynamite), Rock breaker</td>
</tr>
</tbody>
</table>

**Seismic wave velocity**

- Bucket Wheel Excavator: 0, 1.0, 2.0, 3.0 km/sec
- Shovel & Pick Hammer (Man Power)
- Bulldozer, Scraper
- Heavy Power Shovel
- Bulldozer, Scraper (after ripping)
- Bulldozer equipped Ripper (32t class)
- Bulldozer equipped Ripper (43t class)
- Dynamite

**Fig. 6: Margin of Earthmoving Equipment**

Yamazaki 16
The excavation ability of ripper on rock is called ripperability, and is affected by the following factors.

1) Hardness, strength and gap of rock (seismic wave velocity)
2) Direction of crack in rock
3) Ununiformity of rock
4) Working slope
5) Size of bulldozer
6) Number of ripper

Ripperability can be estimated by measuring the seismic wave velocity of rock as one method. A rock has higher seismic wave velocity, harder or more difficult to excavate in general.

Fig. 7 Production estimated graph
D9R Multi or Single Shank No.9 Ripper
Estimated by Seismic Wave Velocities

Fig. 8 Ripperability of rock
103t-Bulldozer with Ripper - CAT D11R
Yamazaki 17

<table>
<thead>
<tr>
<th>Seismic Velocity</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meters Per Second</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feet Per Second x 1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

- TOPSOIL
- CLAY
- GLACIAL TILL
- IGNEOUS ROCKS
- GRANITE
- BASALT
- TRAP ROCK
- SEDIMENTARY ROCKS
- SHALE
- SANDSTONE
- SILTSTONE
- CLAYSTONE
- CONGLOMERATE
- BRECCIA
- CALCITE
- LIMESTONE
- METAMORPHIC ROCKS
- SCHIST
- SLATE
- MINERALS & ORES
- COAL
- IRON ORE

Rippable | Marginal | Non-Rippable

Yamazaki 17
The principle measuring the seismic wave velocity in the field is shown as following.

The thickness of the upper layer of a soil/rock system may be computed by using the following equation:

\[ D_1 = \frac{L_1}{2} \frac{V_2 - V_1}{V_1 + V_2} \]

In most construction applications, we are primarily concerned with the thickness and hardness of the upper soil/rock layer and with the hardness of the second layer. However, in some cases, it may also be desirable to determine the thickness of the second layer and the hardness of the underlying (third) layer. This can be accomplished by using the following equation:

\[ D_2 = \frac{L_2}{2} \frac{V_3 - V_2}{V_2 + V_3} + L_1 \cdot \frac{V_1 V_3^2 - V_1^2 V_3 V_2 V_3^2 - V_1^2}{V_1^3 V_3^2 - V_2^3} \]

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The compacting equipment has many kinds of mechanical characteristics such as static, dynamic vibration or impact to perform an effective compacting material. The adaptability of the various compacting equipments for soil is shown as following.

<table>
<thead>
<tr>
<th>Kinds of soil</th>
<th>Steel Wheel roller</th>
<th>Pneumatic Tire roller</th>
<th>Tamping foot roller</th>
<th>Vibrating roller</th>
<th>Tamper</th>
<th>Bulldozer</th>
<th>Swampdozer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse grained sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand, Sandy soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clayly gravel, Cohesive soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft clay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt paving *)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*) refernce suitable usable

The bulldozer and swampdozer are not compacting equipment, are often used for compacting work when they are used for soil spreading work, as in case of constructing a levee.

![Graph showing the relationship between dry density and number of passes](image)

Yamazaki 19
Fig. 11 Typical compaction equipment

- Smooth, steel wheel roller.
- Self-propelled vibrating roller.
- Small, multi-tired pneumatic roller.
- Heavy pneumatic roller.
- Self-propelled tamping foot roller.
- Self-propelled segmented steel wheel roller.
- Towed sheep's foot roller.
- Grid roller.
In general, the relation between hauling distance and unit cost depending on the equipment can be expressed as follows:

**Fig. 12: Cost and hauling distance**

- **D1**: Max. advantageous Hauling Distance for Bulldozer to Motor Scraper
- **D2**: Max. advantageous Hauling Distance for Bulldozer to Shovel + Dump Truck
- **D3**: Max. advantageous Hauling Distance for Tractor-drawn Scraper to Shovel + Dump Truck

**Table 9: Economic haul distances**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Hauling Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulldozer</td>
<td>Less than 80m</td>
</tr>
<tr>
<td>Scraper</td>
<td>40 – 250m</td>
</tr>
<tr>
<td>Tractor-drawn Scraper</td>
<td>60 – 400m</td>
</tr>
<tr>
<td>Motor Scraper</td>
<td>300 – 2500m</td>
</tr>
<tr>
<td>Shovel &amp; Dump Truck</td>
<td>More than 200m</td>
</tr>
</tbody>
</table>

*It is possible to use Loader in case of less than 100m of Hauling Distance.*

**Fig. 13: General haul distances for mobile systems**

Yamazaki 21
### Table 10: Required width of hauling road

<table>
<thead>
<tr>
<th>Size of Dump Truck</th>
<th>for one way (m)</th>
<th>for double way (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 ~ 11 t</td>
<td>2.0 ~ 5.0</td>
<td>7.0 ~ 12.0</td>
</tr>
<tr>
<td>20 t</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>32 ~ 45 t</td>
<td>8.0 ~ 10.0</td>
<td>14.0 ~ 18.0</td>
</tr>
</tbody>
</table>

### Table 11: Gradeability of Equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Slope (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swamp Bulldozer</td>
<td>40 ~ 55</td>
</tr>
<tr>
<td>Bulldozer</td>
<td>35 ~ 40</td>
</tr>
<tr>
<td>Tractor-pulled scraper</td>
<td>15 ~ 25</td>
</tr>
<tr>
<td>Motor scraper</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Dump truck</td>
<td>&lt; 10</td>
</tr>
</tbody>
</table>

In the gradeability of equipment, crawler type is superior in general. The crawler type vehicle has larger tractive force and wider ground contact area, lower gravity center than that of wheel type.

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![Diagram of Gross Weight](image1)

![Diagram of Gradeability and Speed](image2)

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Yamazaki
The propriety of control equipment affects greatly the quality, cost, term and safety of construction. Therefore proper control for equipment is required. The following must be considered in principle.

1. To adjust and maintain equipments plentifully
2. To reduce waiting time for works
3. To improve operators' ability and enthusiasm
4. To keep as low as possible to change equipments throughout the work
5. To clear off in job fields and to maintain haul road
6. To keep communication between operators and foremen

References
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- http://www.yamazaki.co.jp/