CHAPTER VII.
SUPPORTS FOR BEARINGS.

§ 141.
GENERAL CONSIDERATIONS.

The function of a support for one or more bearings is to hold them in a firm and definite position with regard to the frame or other parts of a machine. Such supports are nearly always made of cast iron, and in the following treatment of the subject this material is the only one considered.

Simple supports are those which are intended to hold but one bearing, in distinction from those supports which are arranged to receive several. In both cases the following considerations should be observed as closely as may be, when, as is usually the case, the shafts which the bearings carry are fitted with gear wheels which should be near the bearings.

1. The bearings should be as near to the hubs of the gear wheels as practicable.
2. The pressure upon the journal should, in no case, act in the direction of the joint between the boxes.
3. The support for the boxes should be so arranged as to allow the easy removal of shafts and gear wheels.

![Fig. 341.](image)

4. The number of bearing surfaces should be made as few as possible, and all finished surfaces should be capable of being finished at one setting on the planing machine.

5. Whenever possible, and especially in situations of difficult access, the bearings should be so disposed that the boxes may be removed and renewed without involving the removal of the shafts from their position.

![Fig. 342.](image)

![Fig. 343.](image)

![Fig. 344.](image)

A simple support for a single pillow block is shown in Fig. 341. It is intended for a bearing such as is shown in § 107, and the upper portion is made correspondingly narrow. The two legs which form the main portions are reinforced by a cross girth, DE. The position of the points D and E may always be well placed by observing the following method: Taking the total height AB as a diameter, draw from the centre O a semi-circle AGB; take the middle point of the arc AB at G; join BG, and prolong it; then draw GH parallel to AB, and draw GC, parallel to HJ, and GC is the height from the base to the cross girth. The dimensions of the various parts are dependent upon the pressure on the bearing, and must usually be governed by the dimensions of the pillow block and by the judgment of the designer. In order to meet the requirements of Rule 5 of the preceding section, there should be under the pillow block a removable plate, which may be given a thickness of 0.15 of.

Fig. 342 is a similar form of support suitable for heavier dimensions.

Fig. 343 is a support for a wall bearing. This is arranged to be built into the wall, and forms an opening through which the shaft can pass, resembling what a builder calls a half's eye window. The pressure of the journal is received by the bracket bearing, which is supported on the key beneath, and can be removed without disturbing the shaft. One point which should not be overlooked is the bearing plate in the wall, shown in tangential dotted lines below the cylinder. The dimensions in the illustration are based on the modulus of the bearing.

A wall bracket support is shown in Fig. 344. This is intended to carry a pillow block, and the T slot for the bolt head forecasts the distance of the bearing from the wall to be adjusted. This form may be used for bearings of various sizes. A simpler and lighter form of bracket is shown in Fig. 345. This is merely an arm attached to a wall and adapted for a horizontal shaft.

Frequently the joint between the base of a bearing support and its foundation is made with cement. When this is done, the base is adjusted to its position, resting upon wedges, and the joint being closed with clay, the liquid cement is run in; this
will harden in a few days so that the wedges may be driven out and the bolts fully tightened.

Fig. 345.

§ 125.

**Multiple Supports for Bearings.**

7 Fig. 346 represents a bridge support. The vertical shaft $AB$ comes from below, as for example, from a turbine, and transmits its motion to the horizontal shaft $CD$. The journal pressure acts at $E$, at right angles to the plane of the two shafts, and at $F$ it acts in an inclined direction downward, both from the pressure of the gear teeth, and also because of the weight of the wheels and shafts. These pressures are best received at $E$, by a yoke bearing as shown in § 113, and at $F$, by a bracket bearing, § 114, supported on an adjusting key.

Fig. 347 shows a support for a step-bearing. Here the horizontal shaft $AB$ runs in a bracket bearing at $C$, and transmits motion to a vertical shaft which is supported at $D$, by a step-bearing, § 116. The latter, as the illustration partially shows, is carried on an adjusting key in such a manner that it can readily be removed from below. The bridge which carries the step-bearing is bolted to the box-shaped base and the nuts for the foundation bolts are placed inside the base.

Another form for similar service is shown in Fig. 348. The shaft $AC$, for the large gear-wheel terminates in the support and is provided with a small bracket bearing at $C$. On account of the position of the wheel, this is not very accessible. The bearings for the vertical shaft $DEF$, are intended to be of the form described in § 120, a yoke bearing being fitted into a space cast in the upper part of the frame at $E$, while an independent

Fig. 346.

Fig. 347.

Fig. 348.

Fig. 349.

Fig. 350.
In Fig. 330 is shown a support for two vertical shafts, A and B, the motion being transmitted from one to the other by means of spur gears. The shaft A, for instance, may be that of a turbine wheel, and B, the main driving shaft of the mill. At A there is a bracket bearing such as shown in Fig. 314, and at B a step bearing, with a removable block beneath it, so that the bearing may be removed or examined without removing the wheel or shaft.

Fig. 355 shows a frame for a vertical shaft A, B, which transmits its motion to a horizontal shaft D, E. At C, is a yoke bearing and at S, a bracket bearing. The horizontal bevel gear is enclosed in the semi-circular frame, so that a cover may easily be adapted, as in the previous case. The removal of the vertical shaft is not quite so convenient in this form as in some others, but the mounting is not very difficult. In some cases the lower part of the frame is entirely closed and the shaft enclosed in a sort of plasiter, to avoid accidents.

For a shaft running parallel to a wall, as at A, B, Fig. 352, and transmitting its motion to one D, E, at right angles, the frame shown in the illustration is suitable. The bearing for the main shaft at C may be a pillow-block, while a bracket bearing is suitable at F. The distance of the pillow-block from the wall is adjustable (as in Fig. 344). If the gears are equal in size the form may be as shown in plan in Fig. 353. In this case the journal at C runs in a bracket bearing. If the construction is intended to fit in the corner of a building, the frame is modified, as shown in Fig. 354; the bearings at C and H are then the same. Both these forms are shown in Fig. 355 and 356 in pseudo-perspective.

Very often a main overhead driving shaft is required to transmit motion to horizontal and vertical shafts from one point, and the combination of Fig. 357 is an example. Here the framework is made a portion of one of the columns of the building and is really simple in construction; at A should be a bracket, and at C, a step bracket, as in Fig. 357, while the bearings at B and D are wall brackets, like Fig. 350.

*Such a frame is used in a spinning mill at Clun, the frame and one half of the large gear wheel being in an archway in the large end wall of the building.
By a proper choice of journal diameters and clearances the seats for the four bearings may be brought into one plane, and the other conditions of § 134 readily complied with.

An examination of the fundamental principles of construction of supports for bearings will show that all forms may be represented by a rigid piece adapted to hold in fixed relation two or more revolving bodies, in such manner as to permit the application of the various details of construction such as boxes, caps, bolts, etc. It is often desirable to sketch out, in the first place, a general scheme of the construction in order that the direction and manner of resistances and arrangement of parts may be examined more readily. The frame shown in Fig. 350 is similar to the elementary shape of Fig. 353, which resembles a simple connecting rod, and which indeed the base plate really is, the

![Diagram](image)

variations being due to the special conditions and not to any fundamental difference. The bridge frame, Fig. 346, is in elementary form Fig. 350. The step supports of Figs. 347 and 348 may be shown in principle either in Figs. 350 or 351, since in these elementary schemes a bearing may be shown either by the journals or the reverse. The four-fold bearing support just described may be sketched in Fig. 362.

To show how these elementary sketches may serve, the following application to one of Lenz's ventilators will indicate.

![Diagram](image)

Here, Fig. 362, nine bearings are to be supported. Three of these are for the drum, which is fast to the driving crank; it is carried by the two neck bearings at A and A', and the thrust bearing at C. The six bearings at D, E, F, G, H, I, are for the rods of the buckets; the supports for all of these are then the beam A, A', the masonry, and the cranked rod B, E, D, C.

§ 127.

Calculations for Iron Columns.

The calculation of the proportions of iron columns often becomes necessary in machine construction, besides serving merely as portions of building construction they are often combined with other details, and also enter into the design of framework as supports and similar relations. Their consideration in this place is therefore appropriate.

Iron columns are generally considered as being subjected to stresses of compression, and, also within certain limits, to bending stresses; it is therefore important to allow sufficient latitude in the calculations to provide for variations in the manner of application of the load.

The various methods of application may be treated as indicated in the following illustrations, Figs. 364, which show the three Cases II, III, and IV, of § 16. The first shows a column hinged at both ends, the second is hinged at one end, while the third is rigidly held at both ends. The breaking loads of the respective forms are:

\[
P = 0.4 \pi \sqrt{\frac{E}{I}} = 3.94 \frac{E}{I} \quad \ldots \ldots \ldots (109)
\]

If \(d\) is the diameter for a solid circular cross section, we have for cast iron, in which \(E = 14,200,000\),

\[
P = 2,750,000 \frac{d^4}{I} \quad \ldots \ldots \ldots (110)
\]

For wrought iron, \(E = 28,400,000\). This gives

\[
P = 5,500,000 \frac{d^4}{I} \quad \ldots \ldots \ldots (111)
\]

Example 1. For a load \(P = 30,000\) lbs., a solid cast iron column 157.5 in. high, the diameter \(d = 0.0245 \sqrt{I} \sqrt{P} = 0.0245 \sqrt{I} \sqrt{P} \), or about 46 in. Under the same conditions a wrought iron column would be 39 1/2 in. diameter.

An inspection of the formula shows that the shorter \(I\) becomes, the smaller is the value of \(d\). The cross section must, however, never be allowed to become so small that the limit of permissible stress shall be passed.

In order that the stress upon the cross section shall not exceed 800 lbs. for either cast or wrought iron (their modulus for compression in either case being 21,500 lbs.), \(d\) should in no case be taken as less than

\[
d = 0.0122 \sqrt{P} \quad \ldots \ldots \ldots (112)
\]

or the load should not be greater than

\[
P = 6397 d^2 \quad \ldots \ldots \ldots (113)
\]

The following table for round solid cast iron posts is calculated from formulas (110) and (112), and gives the loads which may safely be put upon columns of the respective heights and diameters given.

The quantities marked with an asterisk are calculated from formula (112) and are a marked reduction upon the loads otherwise obtained.

* Drewe has tested cast iron columns with a load equal to \(\frac{P}{E}\) without observing perceptible attention. Etzkam's Baukunde, V, p. 524.
STRENGTH OF SOLID CAST IRON COLUMNS.

<table>
<thead>
<tr>
<th>d′</th>
<th>l′ = 8 ft.</th>
<th>10 ft.</th>
<th>12 ft.</th>
<th>14 ft.</th>
<th>16 ft.</th>
<th>18 ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
<td>0.97</td>
<td>1.07</td>
<td>1.13</td>
<td>1.22</td>
<td>1.37</td>
<td>1.53</td>
</tr>
<tr>
<td>1½</td>
<td>1.16</td>
<td>1.21</td>
<td>1.27</td>
<td>1.36</td>
<td>1.50</td>
<td>1.65</td>
</tr>
<tr>
<td>2</td>
<td>1.35</td>
<td>1.41</td>
<td>1.47</td>
<td>1.55</td>
<td>1.69</td>
<td>1.84</td>
</tr>
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<td>1.55</td>
<td>1.61</td>
<td>1.67</td>
<td>1.73</td>
<td>1.86</td>
<td>2.00</td>
</tr>
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<td>1.75</td>
<td>1.81</td>
<td>1.87</td>
<td>1.91</td>
<td>1.95</td>
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<td>2.01</td>
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</tr>
<tr>
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<td>2.15</td>
<td>2.20</td>
<td>2.25</td>
<td>2.28</td>
<td>2.30</td>
<td>2.30</td>
</tr>
</tbody>
</table>

** Hollow Columns.**—Cast iron columns are generally made hollow. The dimensions in this case may readily be determined from the formula for solid columns.

If the external diameter is d′, the internal diameter d′, and the diameter of a solid column of equal strength, d, we have

\[ d = \sqrt[3]{\frac{1}{1 - \left(\frac{d′}{d^3}\right)}} \]  

(125)

The ratio of internal to external diameter \( d′ = \psi \) is conveniently made 0.7 to 0.8. We have for:

\[ \psi = 0.5 \quad 0.6 \quad 0.7 \quad 0.8 \quad 0.85 \quad 0.9 \quad 0.95 \]  

\[ \frac{d}{d′} = 1.016 \quad 1.035 \quad 1.07 \quad 1.10 \quad 1.14 \quad 1.20 \quad 1.31 \quad 1.52 \]

The limits of stress fall within the formula for compression, and the above results are close approximations. It is to be observed that d′ should in no case be taken less than:

\[ d′ = 0.122 \sqrt[3]{\frac{P}{\psi}} \]

or the load greater than.

\[ P = 6397 d′^3 (1 - \psi^3) \]  

(114)

We have for:

\[ \psi = d′ = 0.5 \quad 0.6 \quad 0.7 \quad 0.8 \quad 0.85 \quad 0.9 \quad 0.95 \]  

\[ 1 - \psi^3 = 0.75 \quad 0.64 \quad 0.51 \quad 0.41 \quad 0.32 \quad 0.25 \quad 0.19 \quad 0.10 \]  

\[ \frac{d}{d′} = 1.15 \quad 1.25 \quad 1.30 \quad 1.35 \quad 1.39 \quad 1.45 \quad 1.60 \quad 2.00 \]

Example 1. The solid column of the preceding example to support a load of 3700 pounds was found to be 415/8 inch, and for a ratio of diameters of \( \frac{d}{d′} = 0.95 \) for a hollow column of the same load we have \( d′ = 4.15 \times 4.25 = 0.95 \) for a hollow column of the same load we have \( d′ = 4.15 \times 4.25 = 0.95 \). Substituting these values in (114) we get:

\[ P = 6397 d′^3 (1 - \psi^3) \]

This gives the maximum safe load. In the case of hollow columns the strength of the metal of 0.65″.

In practice it is often necessary to work to a given external diameter d′, in which case, for cast iron, the internal diameter d′, may be found from:

\[ d′ = d″ \sqrt{1 - \frac{0.0000966 \times 10^{–6} \times d′}{P}} \]

and the load

\[ P = 2,500,000 d′^3 - d″^4 \]  

(115)

in which \( P \) is the difference in supporting capacity between two solid columns of the diameters \( d′ \) and \( d″ \), respectively.

It is necessary also in this case to observe that \( P \) should not be greater than

\[ d″ = d′ \sqrt{1 - \frac{0.0000966 \times 10^{–6} \times d′}{P}} \]  

(116)

in order that satisfactory castings may be produced.

Example 5. In a barracks in Berlin are hollow columns of 10 inches height, bearing loads of 3700 lbs. These are made of diameter \( d′ = 6\frac{1}{8}″ \) according to (109) this should give the internal diameter:

\[ d″ = 6.18 \sqrt{1 - \frac{0.0000966 \times 10^{–6} \times 3700 \times 10^{3}}{2.5 \times 10^{6}}} = 5.99″ \]

This gives a thickness of metal of 0.65″. The empirical thickness for such a column is about 0.7″, and the actual internal diameter was 5.99″.

Example 4. A cast iron column of 10 inches height and 6.3 inches outside diameter has to bear a load of 3700 lbs., and was made with an internal diameter of 6.94 inches. According to (113) for direct resistance to thrust we get:

\[ d″ = 6.18 \sqrt{1 - \frac{0.0000966 \times 10^{–6} \times 3700 \times 10^{3}}{2.5 \times 10^{6}}} = 5.99″ \]

but according to (116):

\[ d″ = 6.3 \sqrt{1 - \frac{0.0000966 \times 10^{–6} \times 3700 \times 10^{3}}{2.5 \times 10^{6}}} = 6.69″ \]

or very near the actual dimensions.

These examples show how important it is to take all the conditions into account, in order to avoid errors and a careful examination of the circumstances attending each case should always be considered.

**Plated Columns.**—The cruciform section may serve as an example of such columns. The thickness and breadth, \( b \) and \( h \), of the ribs may be determined by comparison with the diameter \( d′ \), of an equal round solid column by making:

\[ \frac{b}{h} = \frac{3}{16} \left( \frac{d′}{h} \right) = 0.19 \left( \frac{d′}{h} \right)^{1.77} \]  

(117)

from which the approximate thickness \( b \), for any breadth \( h \), may be obtained. In order to keep within safe limits the cross section should not be less than:

\[ b = \frac{P}{17000} \]

or the load more than

\[ P = 270,000 b \]  

(118)

Example 2. To substitute a cruciform column for the solid one of Example 4, we may take \( b = 4.53 \times 4.25 \). We then have from (117):

\[ \frac{b}{h} = 4.15 \times 4.25 \]

The safe load according to (118) would be:

\[ P = 17,000 \times 6.32 \times 0.72 = 76,000 \text{ lbs.} \]

For a direct calculation of \( b \) and \( h \) we may use the following:

\[ b = \frac{30}{14,300,000 \times 0.5 \times h^2} = \frac{0.0000966 \times 10^{–6} \times 14,300,000 \times 0.5 \times h^2}{P} \]

and hence:

\[ P = 4,752,000 b h^3 \]  

(119)

Care should be taken that the load does not exceed the limit given by (118).

Example 6. In the new building of the sugar refinery of Waalburg, built in 1830, are columns of cruciform section.

Those in the basement bear a load of 3700 lbs., and are 24″ high, the ribs being 3″ by 24″. According to (118) these posts should sustain a load of

\[ P = 4,250,000 \times 0.5 \times 24 \]  

(118)

\[ P = 4,250,000 \times 0.5 \times 24 = 44,500 \text{ lbs.} \]

which is much more than the actual load.

**Columns of Angle and T Iron.**—These are much used in bridge trusses, especially in America. (See § 87.) The vertical posts may be considered as columns with jointed ends. Case I, Fig. 344, and the upper chord in compression and may be considered as Case III, Fig. 344. The following figures show many of the forms, in section, which may be used for this purpose.
THE CONSTRUCTOR.

ing flat iron between the joints of the segments. The four following sections are from the Keystone Bridge Works.

The sectional distribution of material should be chosen so that the equation moment of inertia on both the principal axes are the same (see Fig. 14). The fifth section shows a double T iron, in the middle in dotted lines. This is used in bridge chords, where two or more such shapes are sometimes introduced. The last form is a combination of four pieces of angle iron recently used for pumy rods in mine shafts. The resistance to thrust is here dependent upon the distance between the girdles of the rod.

Gross's Column.—It is sometimes a question whether, in the support of very important loads, as well as for economy of material, it is not best to use two or three columns instead of one. If we let n be the number used, instead of one, we have, for the supposition that the columns are in compression, the relation for similar sections.

\[ P' = \sqrt{n} P \]  \hspace{1.5cm} (120)

This shows that grouped columns use \( \sqrt{n} \) times as much material as a single column. It is also economy of material to use a small number of heavily loaded columns to sustain a given load.

Example 5. This subject may also be treated by the aid of the preceding table. If we have a load of 300,000 lbs. upon a column 12 feet high, the diameter for a solid round column would be 36\(\frac{1}{4}\) in., while for four columns of 3 inches diameter we have 4 \times 75 = 300, or about the same. The cross sections are to each other as (14) (28) (279), or as 5 4 0.58 or \( \sqrt{1.4} \). Variations in the height of columns affect the economy of material, other things being equal, to a marked degree, since the resistance to compression varies directly as the height (h).

It is sometimes desirable to make a column in several parts, when a proportional reduction in height can thereby be secured. The triple central core of the column shown in Fig. 368, is an example and is a form often used by architects in connection with columns of brickwork. This is not as effective as a single column, since the column ratio is \( \frac{1}{2} \) \( \sqrt{\frac{1}{3}} \), i.e., \( \frac{1}{2} \) \( \sqrt{3} \) = 0.866.

In conclusion it must be remarked that the columns which are used in machine construction are usually made much heavier than the preceding calculations indicate. This is due to the fact that such columns are often subjected to bending and tensional stresses, as well as to much vibration and the additional material is needed to meet these conditions. Columns of cast iron which are subjected to tension, as in the framing of vertical engines, should be made at least double the section given by (120), (121), (116), and (118). The security is also made greater in the case of buildings, as the result in Example 6 shows.

128.

FORMS FOR IRON COLUMNS.

The columns which are used in machine construction must be held down to the iron base plates of the machines, or if used in connection with building construction are secured to foundations of masonry. Heavily loaded columns are often placed upon foundation stones with only a short load beam, and no fastening, but otherwise some form of anchorage must be used.

The illustrations show three forms of fastening. In each case the lower plate is placed beneath the pavement. In the first case a special form of bolt is used which is bolted to the masonry by an anchor bolt; in the second the flange which is cast on the column is bolted to the keys shown; the third construction (by

Horsig) is arranged with a short cylinder bolted to the faced sole plate and made so as to give a space in which filled lead may be poured after the column is set in its exact position. A hole is left in the side of the column to admit the melted metal. The portion of the base of the column which shows above the pavement is made to conform to the general style of the building. In Fig. 369 a simple moulding is used between the plinth and shaft; in Fig. 370 a bead is added, and in Fig. 371 a double moulding of more elaborate outline is used.

The capitals of such columns are made in many varied forms. Fig. 372 shows, in section and elevation, a capital arranged to carry a beam and to support the base of the column of the floor above. A recess in the top of the column receives the main beam, and affords a good place for a joint. If iron beams are used, this recess is made proportionately narrower. The base of the upper column is securely bolted down as shown.*

The capitals of iron columns afford much opportunity for effective decoration, which in many cases is neglected, although comparatively easy of execution. For the lower columns of heavy buildings the simple cubic capital so often found in Romanesque buildings is most suitable, and a good example is shown in Fig. 373.

The illustrations show three forms of fastening. In each case the lower plate is placed beneath the pavement. In the first case a special form of sole plate is held down to the masonry by an anchor bolt; in the second the flange which is cast on the column is bolted to the keys shown; the third construction (by

* Other forms will be found in F. Brandt's Eisenkonstrukt, Berlin, 1884.
† Shown among other places in the Osterland, Lloyd, in Trieste, and in the Arsenal at Vienna.

Fig. 368.

Fig. 369.

Fig. 370.

Fig. 371.

Fig. 372.

Fig. 373.

Fig. 374.

Fig. 375.

Fig. 376.

Fig. 377.

Fig. 378.

The illustrations show three forms of fastening. In each case the lower plate is placed beneath the pavement. In the first case a special form of sole plate is held down to the masonry by an anchor bolt; in the second the flange which is cast on the column is bolted to the keys shown; the third construction (by

* For example, the columns in the vestibule of the theatre at Carlsruhe.