according to the first embodiment of the present invention;

FIG. 5 is a view taken along the line V-V of FIG. 4.

FIG. 6 is a view taken along the line VI-VI of FIG. 4.

FIG. 7 is a vertical sectional view illustrating a steel damper for seismic isolation according to a second embodiment of the present invention;

FIG. 8 is a vertical sectional view illustrating a main part of a steel damper for seismic isolation according to a third embodiment of the present invention;

FIG. 9 is a view taken along the line IX-IX of FIG. 8;

FIG. 10 is a view taken along the line X-X of FIG. 8;

FIG. 11 is a perspective view illustrating a steel damper for seismic isolation according to a fourth embodiment of the present invention;

FIG. 12 is a vertical sectional view illustrating a main part of the steel damper for seismic isolation according to the fourth embodiment;

FIG. 13 is a view taken along the line XIII-XIII of FIG. 12;

FIG. 14 is a view taken along the line XIV-XIV of FIG. 12;

FIG. 15 is a perspective view illustrating an FEM analysis model of a seismic isolation plate according to a fifth embodiment of the present invention;

part 17a that extends parallel to the upper fixing part 16a with the same dimension in the longitudinal direction as the dimension of the upper fixing part 16a, and is fixed to the lower board 11; a flat plate-shaped upper inclined part 18a and a lower inclined part 19a extending at the same inclination angle θ to be closer to each other while being separated from the upper fixing part 16a and the lower fixing part 17a; and a connecting part 20a that connects the upper inclined part 18a and the lower inclined part 19a to each other.

[0018]

As illustrated in FIGS. 3A and 3B, a plurality of bolt through-holes is formed in the upper fixing part 16a. A plurality of bolt through-holes is also formed in the lower fixing part 17a. Then, as illustrated in FIG. 3B, the upper inclined part 18a of the seismic isolation plate 15a is formed such that a width dimension M gradually decreases from the upper fixing part 16a toward the connecting part 20a, and the lower inclined part 19a is formed such that the width dimension M also gradually decreases from the lower fixing part 17a toward the connecting part 20a.

Further, the other three seismic isolation plates 15b, 15c, and 15d are also members having the same shape as the shape of the above-described seismic isolation plate 15a, and the parts having the same configuration as the configuration of the parts that configure the seismic

the energy of seismic motion can be sufficiently absorbed.

Further, the seismic isolation plates 15a, 15b, 15c, and 15d of the first embodiment can be manufactured by using a general steel sheet bending machine. Here, the general steel sheet bending machine is a device of which the maximum bending depth is limited to approximately 850 mm when the bending height of the steel sheet is approximately 500 mm.

[0032]

When the bending height H is set to 500 mm, the maximum bending depth when manufacturing the seismic isolation plates 15a, 15b, 15c, and 15d is a dimension (D + L) obtained by adding the dimension D (refer to FIG. 3A) of the upper fixing parts 16a, 16b, 16c, and 16d (lower fixing parts 17a, 17b, 17c, and 17d) in the longitudinal direction, and the dimension L of the upper inclined parts 18a, 18b, 18c, and 18d (lower inclined parts 19a, 19b, 19c, and 19d) in the longitudinal direction.

[0033]

The upper fixing parts 16a, 16b, 16c, and 16d (lower fixing parts 17a, 17b, 17c, and 17d) are bolted to the upper board 10 while the upper fixing parts 16a, 16b, 16c, and 16d of the seismic isolation plates 15a, 15b, 15c, and 15d do not overlap each other, and the lower fixing parts 17a, 17b, 17c, and 17d of the seismic isolation plates 15a, 15b, 15c, and 15d are also bolted

and the lower board 11 are arranged extending in the cross direction in a plan view.

[0042]

As illustrated in FIG. 8, the first seismic isolation plate 32a includes an upper split steel sheet 33a and a lower split steel sheet 34a. The upper split steel sheet 33a includes an upper fixing part 35a provided at the center part in the longitudinal direction; a pair of upper inclined parts 36a and 37a bent diagonally downward from both ends of the upper fixing part 35a in the longitudinal direction; and upper connecting parts 38a and 39a bent downward from the end parts of the pair of the upper inclined parts 36a and 37a. Further, the lower split steel sheet 34a includes a lower fixing part 40a provided at the center part in the longitudinal direction; a pair of lower inclined parts 41a and 42a bent diagonally upward from both ends of the lower fixing part 40a in the longitudinal direction; and lower connecting parts 43a and 44a bent upward from the end parts of the pair of the lower inclined parts 41a and 42a.

[0043]

The upper split steel sheet 33a and the lower split steel sheet 34a are integrated by connecting the upper connecting parts 38a and 39a and the lower connecting parts 43a and 44a. In other words, as illustrated in FIG. 8, in a state where the upper connecting parts 38a and 39a and the lower connecting parts 43a and 44a face

each other, by sandwiching the facing parts between fourth and fifth splice plates 45 and 46, inserting connecting bolts 47 to the fourth and fifth splice plates 45 and 46, and screwing the connecting bolts 47 with nuts 48, the upper split steel sheet 33a and the lower split steel sheet 34a are integrated to form the first seismic isolation plate 32a. The pair of upper inclined parts 36a, 37a and the pair of lower inclined parts 41a and 42a of the first seismic isolation plate 32a have a shape in which the width dimension M gradually decreases while being separated from the upper fixing part 35a and the lower fixing part 40a.

[0044]

Meanwhile, the second seismic isolation plate 32b also includes an upper split steel sheet 33b and a lower split steel sheet 34b, as illustrated in FIGS. 9 and 10. The upper split steel sheet 33b includes an upper fixing part 35b provided at the center part in the longitudinal direction; a pair of upper inclined parts 36b and 37b bent diagonally downward from both ends of the upper fixing part 35b in the longitudinal direction; and upper connecting parts 38b and 39b bent downward from the end parts of the pair of the upper inclined parts 36b and 37b. Further, the lower split steel sheet 34b includes a lower fixing part 40b provided at the center part in the longitudinal direction; a pair of lower inclined parts 41b and 42b bent diagonally upward from both ends of the lower fixing part 40b in the longitudinal direction; and

isolation plates 15a, 15b, 15c, and 15d are firmly tightened and fixed by the connecting bolts 22 and the nuts 23 in a state of being sandwiched between the upper board 10 and the four third splice plates 51 from the thickness direction, and the lower fixing parts 17a, 17b, 17c, and 17d of the seismic isolation plates 15a, 15b, 15c, and 15d are firmly tightened and fixed by the connecting bolts 25 and the nuts 26 in a state of being sandwiched between the lower board 11 and the four third splice plates 52 from the thickness direction.

[0055]

Further, each of the four third splice plates 51 is arranged to straddle the pair of adjacent upper fixing parts 16a and 16c, the pair of adjacent upper fixing parts 16b and 16c, the pair of adjacent upper fixing parts 16b and 16d, and the pair of adjacent upper fixing parts 16a and 16d of the seismic isolation plates 15a, 15b, 15c, and 15d. Accordingly, all of the upper fixing parts 16a, 16b, 16c, and 16d including the end parts of the upper fixing parts 16a, 16b, 16c, and 16d are restrained, and local plastic deformation of the upper fixing parts 16a, 16b, 16c, and 16d can be deterred. Further, by suppressing the local deformation of the upper fixing parts 16a, 16b, 16c, and 16d, the stress concentration of the connecting bolt 22 can be prevented. Further, each of the four third splice plates 51 is arranged to straddle the pair of adjacent lower fixing parts 17a and 17d, the pair of adjacent lower fixing

parts 17b and 17d, the pair of adjacent lower fixing parts 17b and 17c, and the pair of adjacent lower fixing parts 17a and 17c of the seismic isolation plates 15a, 15b, 15c, and 15d. Accordingly, all of the lower fixing parts 17a, 17b, 17c, and 17d including the end parts of the lower fixing parts 17a, 17b, 17c, and 17d are restrained, local plastic deformation of the lower fixing parts 17a, 17b, 17c, and 17d can be deterred, and the stress concentration of the bolt 25 can also be prevented.

[0056]

Therefore, in the steel damper for seismic isolation 6 of the present embodiment, local plastic deformation of the upper fixing parts 16a, 16b, 16c, and 16d and the lower fixing parts 17a, 17b, 17c, and 17d when the energy of seismic motion is transmitted is reliably deterred, and absorbency of energy of seismic motion can be prevented from decreasing.

[0057]

[Fifth Embodiment]

Next, in a fifth embodiment illustrated in FIGS. 15 to 19, a range of an appropriate inclination angle θ of the four seismic isolation plates 15a, 15b, 15c, and 15d, which are used in the steel damper for seismic isolation 6 of the first, second, and fourth embodiments, is set.

In the present embodiment, an FEM analysis model 15 of the seismic isolation plate illustrated in FIG. 15 is used. The FEM analysis model 15 of the seismic isolation

plate of FIG. 15 has a structure corresponding to the seismic isolation plate 15a illustrated in FIG. 3A, the upper fixing part 16 corresponds to the upper fixing part 16a of the seismic isolation plate 15a, the lower fixing part 17 corresponds to the lower fixing part 17a of the seismic isolation plate 15a, the upper inclined part 18 and the lower inclined part 19 correspond to the upper inclined part 18a and the lower inclined part 19a of the seismic isolation plate 15a, and the connecting part 20 corresponds to the connecting part 20a of the seismic isolation plate 15a. Further, the FEM analysis model 15 of the seismic isolation plate of FIG. 15 has a structure corresponding to other seismic isolation plates 15b, 15c, and 15d.

[0058]

The FEM analysis model of a seismic isolation plate 15 includes the upper fixing part 16, the lower fixing part 17, the upper inclined part 18, the lower inclined part 19, and the connecting part 20 having the dimensions and shapes illustrated in FIG. 16. As illustrated in FIGS. 17A to 17G, a plurality of types of FEM analysis models (models M1 to M7) having different inclination angles θ is provided.

FIG. 17A illustrates the model M1 as a comparative example in which the inclination angle θ is 0°, and FIGS. 17B to 17G illustrate the models M2 to M7 in which the inclination angle is set to 2.6° to 19.7°. The unit of

the shape dimension illustrated in FIGS. 16 and 17B to 17G is (mm).

Then, by setting the lower fixing parts 17 of the models M1 to M7 in a fixed state, applying a load in the direction (loading direction) along the longitudinal direction of the upper fixing part 16, and displacing the upper fixing part 16 to 400 mm in the loading direction, the equivalent plastic strain of the upper inclined part 18 and the connecting part 20 was confirmed.

[0059]

FIG. 18 is a diagram in which the maximum value of the equivalent plastic strain of the upper inclined part 18 and the connecting part 20 of the models M1 to M7 is plotted with the inclination angle θ on the horizontal axis and the equivalent plastic strain on the vertical axis. In a case of the model M1 (θ = 0°) and the model M2 (θ = 2.6°), the equivalent plastic strain of the connecting part 20 is significantly smaller than the equivalent plastic strain of the upper inclined part 18, and thus the absorbency of energy of seismic motion due to plastic deformation cannot be exhibited. Further, in a case of the model M6 (θ = 17.7°) and the model M7 (θ = 19.7°), the equivalent plastic strain significantly increases, and there is a concern that the fatigue durability against repeated load during an earthquake is insufficient. Meanwhile, in a case of the model M3 (θ = 5.2°), the model M4 (θ = 10.3°), and the model M5 (θ = 15.3°), the equivalent plastic strain of the upper