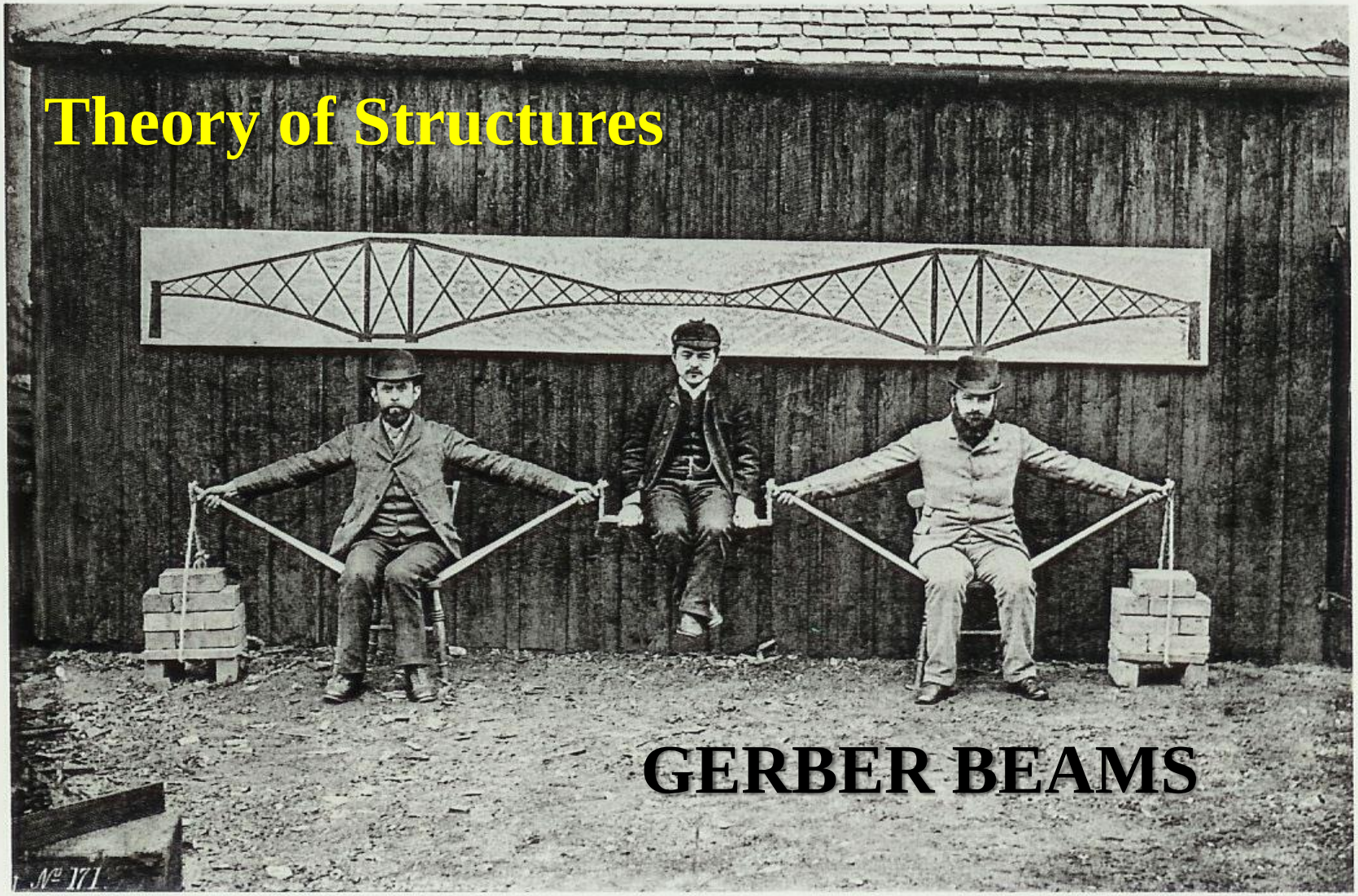
Theory of Structures



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Quebec Bridge (L=549m)
Quebec city, Canada
1917

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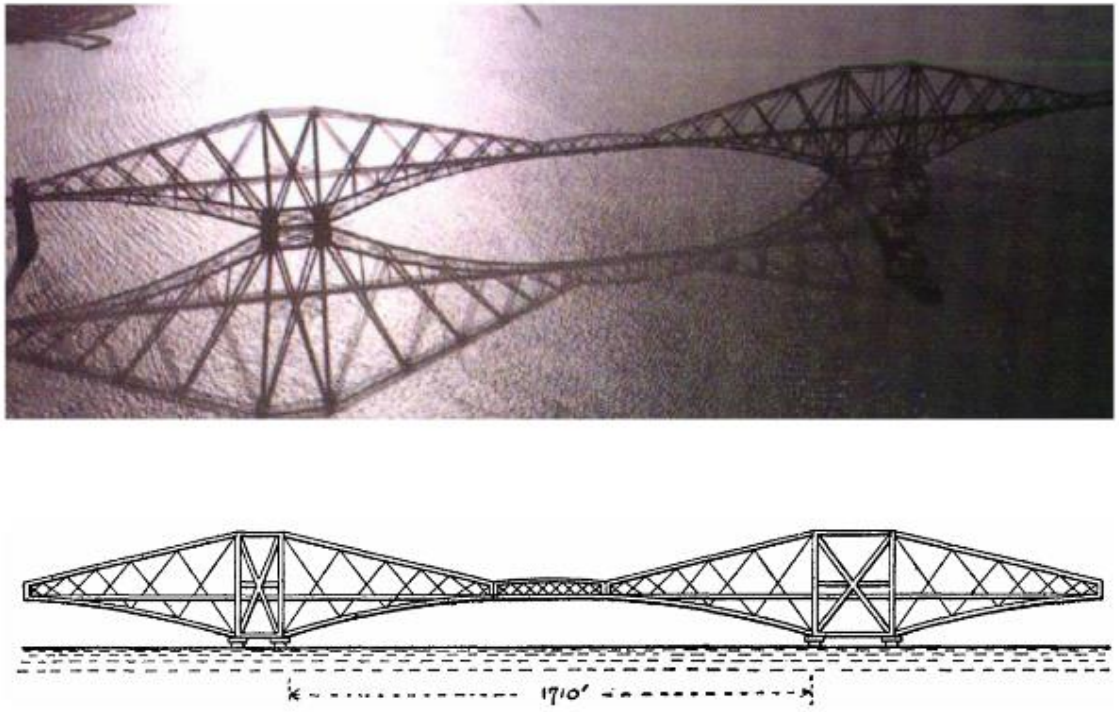

Fifth of fourth (L=521m)
Edimburgh, UK
1890

Static Determinacy of Internally Stable Structures

An internally stable structure is considered to be *statically determinate externally if all its support reactions can be determined by solving the equations of equilibrium*. Since a plane internally stable structure can be treated as a plane rigid body, in order for it to be in equilibrium under a general system of coplanar loads, it must be supported by at least three reactions that satisfy the three equations of equilibrium

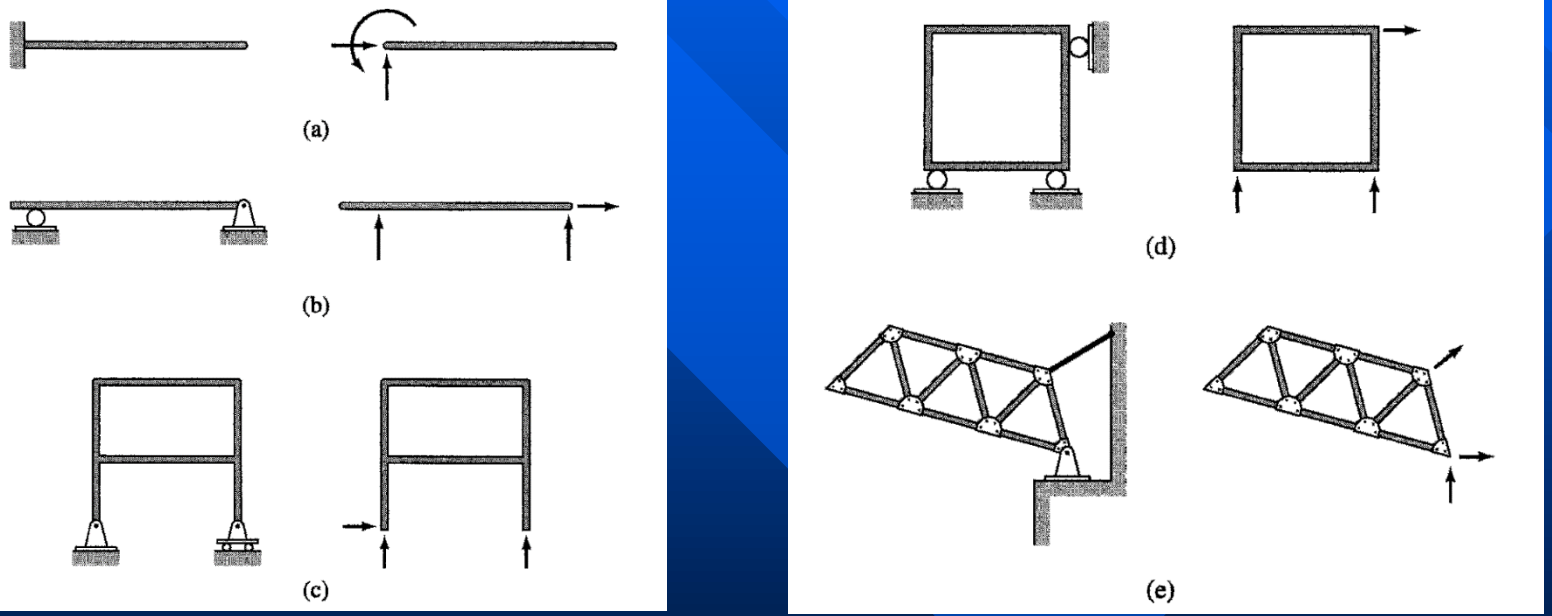

FIG. 3.9 Examples of Externally Statically Determinate Plane Structures

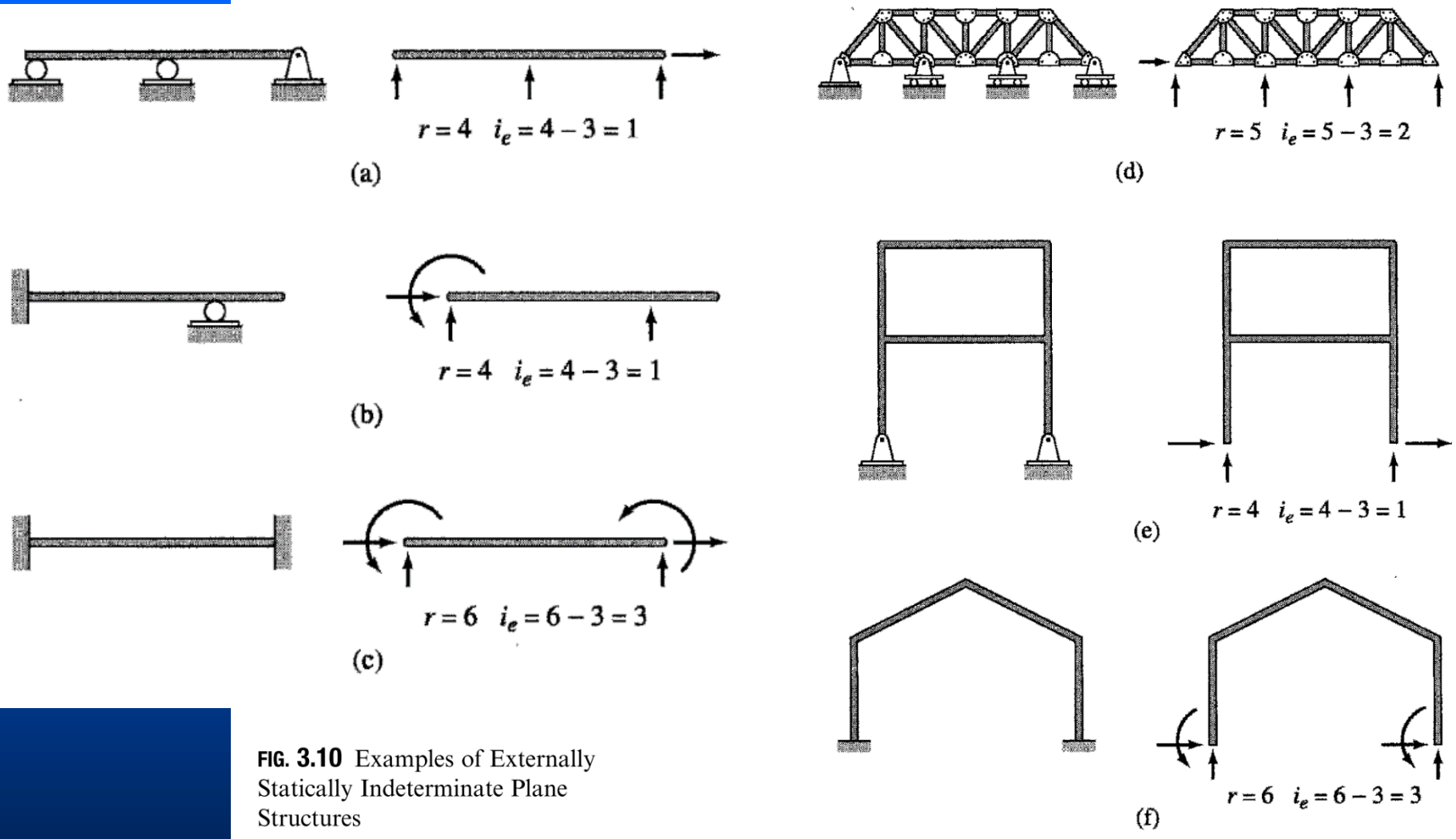

FIG. 3.10 Examples of Externally Statically Indeterminate Plane Structures

If a structure is supported by more than three reactions, then all the reactions cannot be determined from the three equations of equilibrium. Such structures are termed *statically indeterminate externally*. The reactions in excess of those necessary for equilibrium are called *external redundants*, and the number of external redundants is referred to as the *degree of external indeterminacy*. Thus, if a structure has r reactions $(r > 3)$, then the degree of external indeterminacy can be written as

$$i_e = r - 3 \tag{3.7}$$

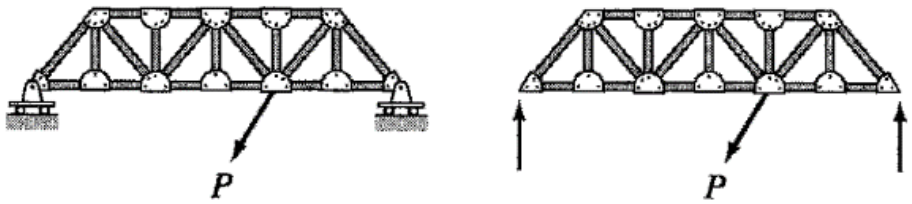

FIG. 3.11 An Example of Externally Statically Unstable Plane Structure

referred to as *geometrically unstable externally*. The two types of reaction arrangements that cause geometric instability in plane structures are shown in Fig. 3.12. The truss in Fig. 3.12(a) is supported by three parallel reactions. It can be seen from this figure that although there is a sufficient number of reactions ($r = 3$), all of them are in the vertical direction, so they cannot prevent translation of the structure in the horizontal direction. The truss is, therefore, geometrically unstable. The other type of reaction arrangement that causes geometric instability is shown in Fig. 3.12(b). In this case, the beam is supported by three nonparallel reactions. However, since the lines of action of all three reaction forces are concurrent at the same point, A, they cannot prevent rotation of the beam about point A. In other words, the moment equilibrium equation $\sum M_A = 0$ cannot be satisfied for a general system of coplanar loads applied to the beam. The beam is, therefore, geometrically unstable.

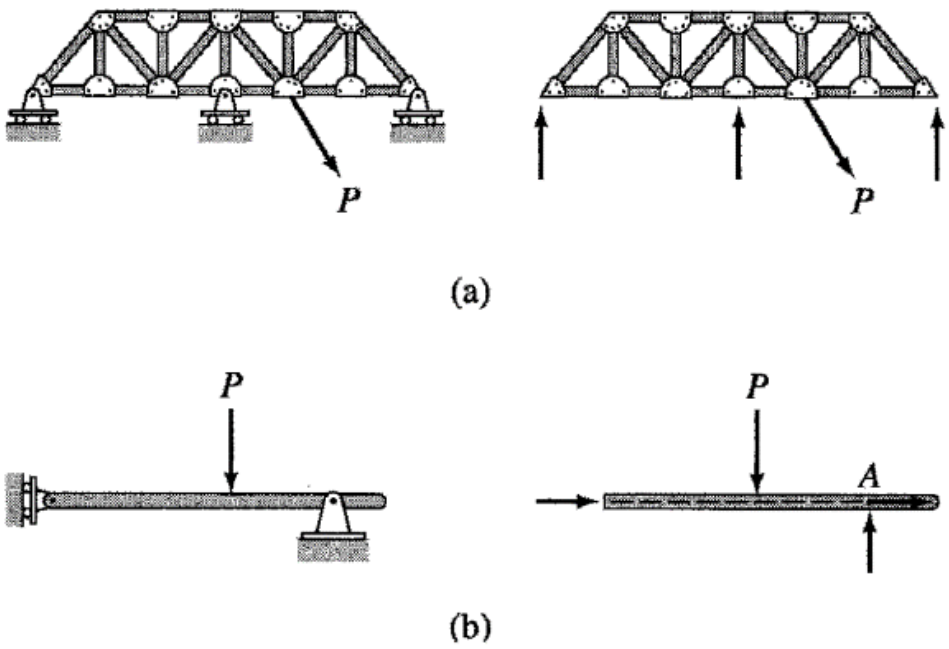

FIG. 3.12 Reaction Arrangements Causing External Geometric Instability in Plane Structures

The conditions of static instability, determinacy, and indeterminacy of plane internally stable structures can be summarized as follows:

$$\begin{aligned} r < 3 &\quad \text{the structure is statically unstable externally} \\ r = 3 &\quad \text{the structure is statically determinate externally} \\ r > 3 &\quad \text{the structure is statically indeterminate externally} \end{aligned} \tag{3.8}$$

where r = number of reactions.

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for the system shown in Fig. 11.2(a) with its central *cantilever beam* EF (overhang at both ends) and *propped beams* AE, FD on either side. The system shown in Fig. 11.2(b), with the cantilever beam ABE (overhang at one end), the *coupling beam* EF and the propped beam FD

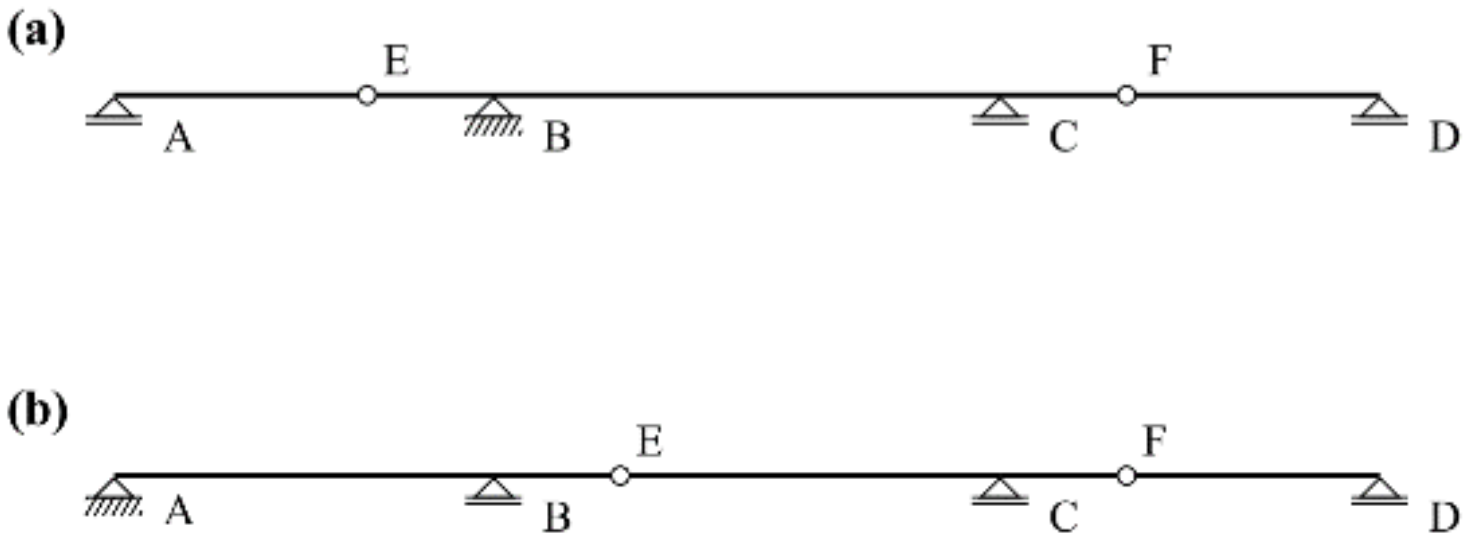

Fig. 11.2 Hinged girder: (a) cantilever beam EF with propped beams AE, FD, (b) coupling beam EF, (c) suspended beam HI with inadmissible hinge J in adjacent end span EF, (d) suspended beam GH with inadmissible suspended beam IJ in adjacent interior span CD

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The flexural hinges must be introduced in such a way that they do not cause a *chain of hinges*. Therefore, interior spans may have no more than two hinges, end spans no more than one. In addition, with a *suspended beam*, there should be neither propped beams in the adjacent end spans nor suspended beams in the adjacent interior spans; Fig. 11.2(c) and (d) illustrate the mechanisms otherwise possible – both systems are kinematically unstable

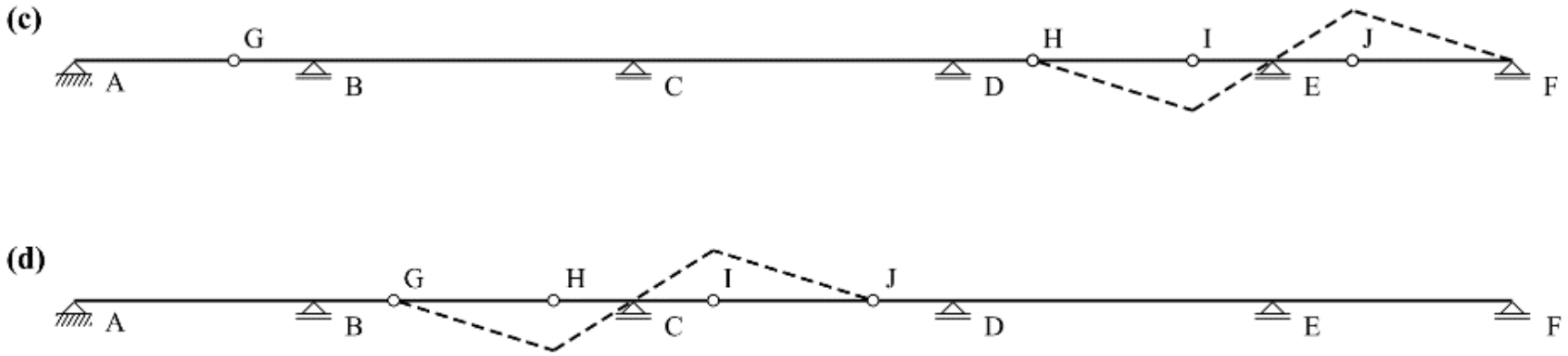

Fig. 11.2 Hinged girder: (a) cantilever beam EF with propped beams AE, FD, (b) coupling beam EF, (c) suspended beam HI with inadmissible hinge J in adjacent end span EF, (d) suspended beam GH with inadmissible suspended beam IJ in adjacent interior span CD