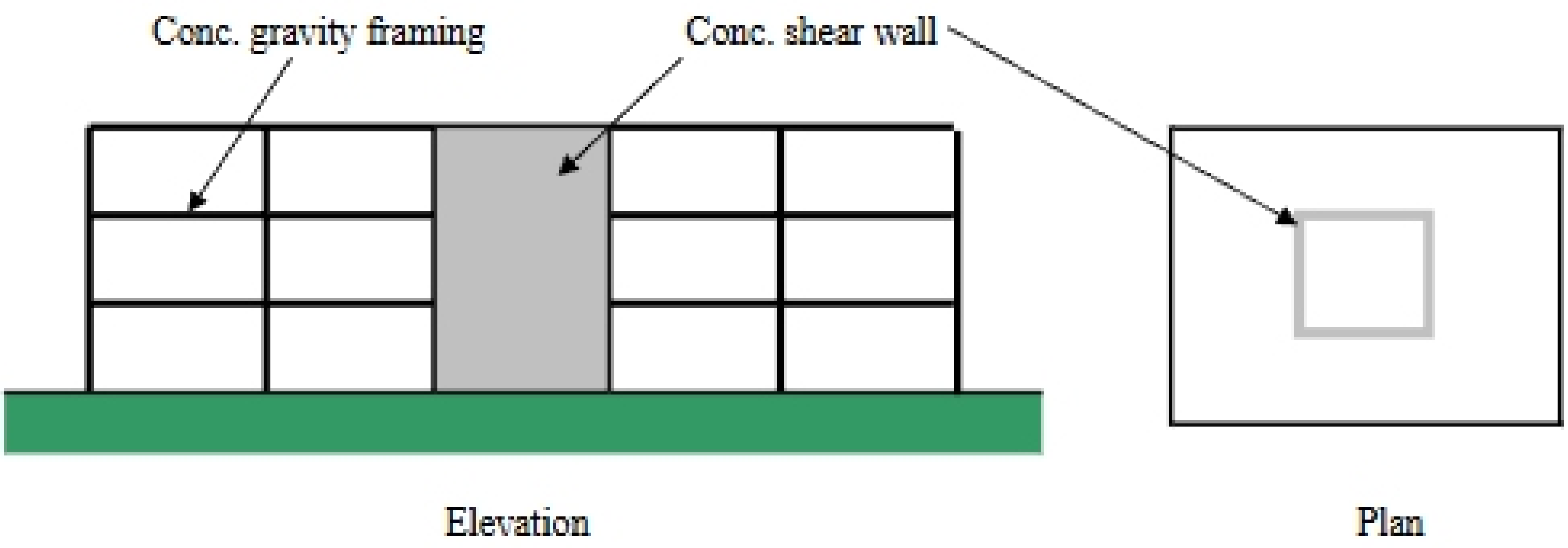
Problem 7 – Conceptual Design

In this problem, we investigate various structural configurations for our building. I've presented a sketch of possible solutions here, but obviously yours may (and likely will) differ. What is important is to recognize how various structural systems/configurations are evaluated, since this process is done early in a project to narrow down the range of possible structural solutions.

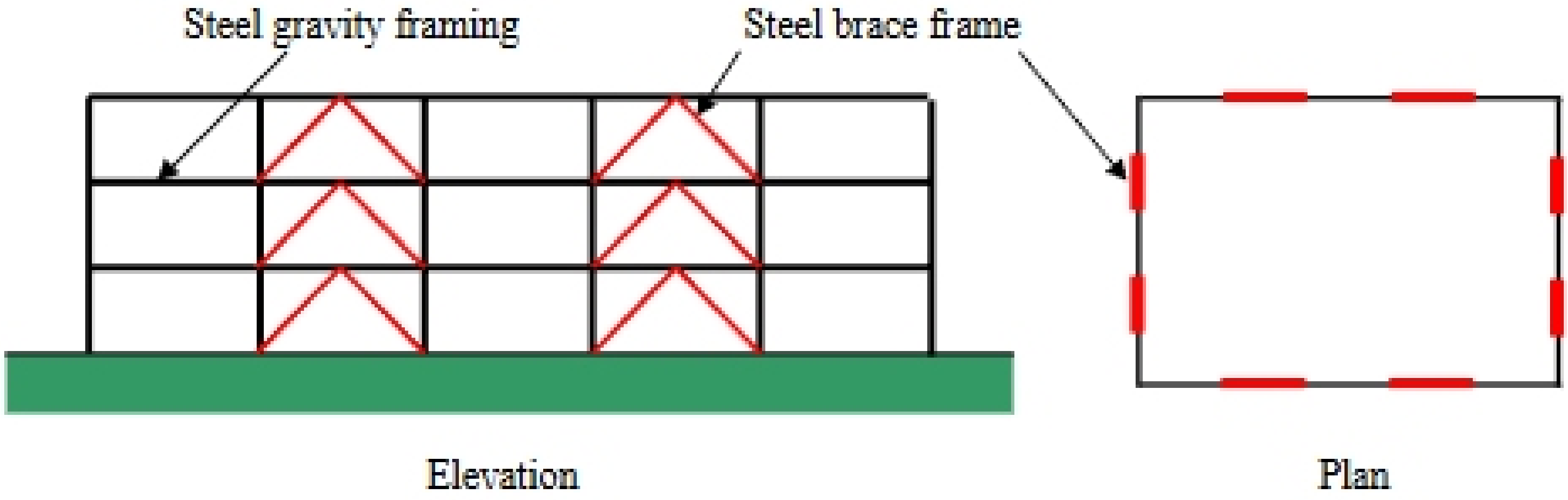
Option 1 – Concrete Core Shear Wall



Advantages: Concrete is an inexpensive and effective building material, especially for wall construction. Concrete walls can be detailed with boundary elements and field steel for reliable, ductile cyclic response. Since concrete shear walls are generally quite stiff, the expected inelastic drifts should be very low.

Disadvantages: Walls would probably be clustered around elevator cores, which are often located toward the center of the floor plate. This leads to torsional flexibility of the building, and large drifts from accidental mass eccentricity. Also, shear walls located just at the core would develop very large overturning moments in a relatively narrow element, leading to significant uplift forces, and hence expensive foundations.

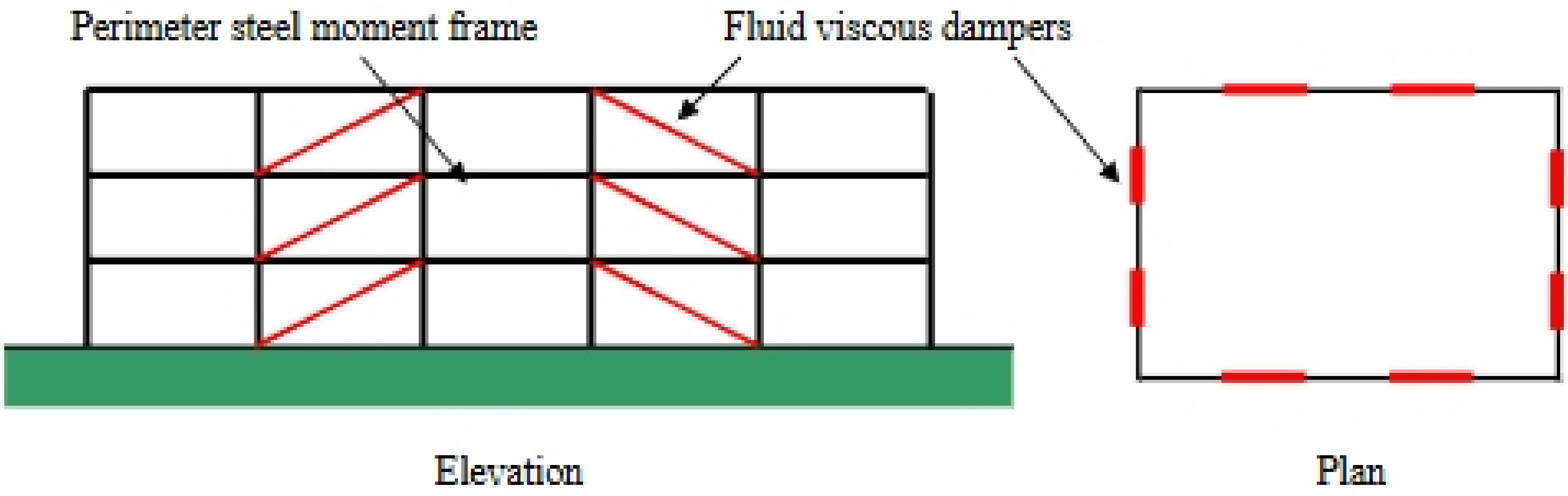
Option 2 – Steel Brace Frame



Advantages: Steel braces combine strength and stiffness with versatility and ease of construction. Properly detailed, steel brace frames require very little field welding (which is very expensive compared to shop welding) and fast, efficient construction. In addition to being stiff, certain classes of steel brace frames provide significant ductility capacity and stable hysteresis. Such ductile brace frames include eccentrically braced frames (EBF's) and buckling-restrained braced frames (BRBF's.) These will be discussed further in class.

Disadvantages: While some brace frames are ductile, others are not. Specifically, concentric brace frames are designed to buckle in compression and yield in tension. Even under the best detailing conditions, these frames to not dissipate significant energy per cycle of displacement, and are susceptible to low-cycle fatigue (that relates to several cycles of large plastic strain in the buckled region of the brace.) In addition to their questionable seismic performance, braces can be obstructive in terms of openings and windows. While considered by some as an aesthetic structural expression, most mainstream architects have been hesitant to embrace this rather utilitarian design paradigm. Also, gusset plates can shorten the effective length of the column, causing yielding.

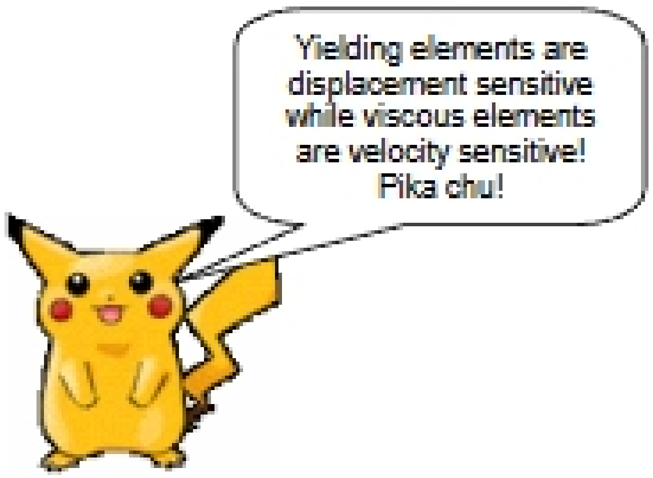
Option 3 – Steel Moment Frame with Viscous Fluid Dampers (VFD)



Fluid viscous dampers are passive energy dissipation devices that are supplemental to another lateral system. They are passive because they do *not* change properties depending on their response (for example, magneto-rheological devices are semi-active because they have fluid that has suspended iron filaments, and when a current is applied, the viscosity of the fluid changes.) Also, dampers cannot be the sole lateral system in a building, that is, you can't have all pinned connections with dampers as shown above. The frame would just fall over during a windstorm.

Advantages: Advantages are that dampers significantly reduce the story drifts in a moment frame structure without increasing the demands to structural elements. This is because the maximum damping force occurs at the moment of maximum velocity, whereas the maximum elastic spring force occurs at the moment of maximum displacements (from elementary dynamics you know that the maximum displacement occurs at zero velocity, and vice-versa.) In addition, floor accelerations remain low even at reduced drifts because the period is not being altered appreciably (recall the damped natural frequency is very close to the undamped natural frequency, even at moderate levels of damping.)

Disadvantages: Dampers cost serious cash. Not only are the devices themselves pricey (around $8K apiece for 500 kip capacity) but there is typically a mandatory testing program where each device to be installed in a building goes through a series of production tests to verify its performance at varying levels of stroke and velocity. Also, they still block doorways and windows. And they can leak (allegedly.)



Incidentally, there are many such devices, including viscoelastic dampers (having both damping and stiffness), friction dampers, lead extrusion dampers, yielding steel plate dampers, and other inventions whose purpose is to supplement the energy dissipation of the primary lateral system.