The sky's the Limit?

In the Physics Student Book Section 4.2 Better Buildings, there is a short discussion of material properties needed for tall buildings: stiffness, strength, low density. But an article in the recent magazine "Extreme Engineering' seems to suggest that height limits for buildings are more financial than technological. Which is right?

What you need

- Advancing Physics Student Book, Chapter 4
- (useful but not essential) Alden M Hayashi, 'The Sky's the Limit', in Scientific American Presents 'Extreme Engineering' Volume 10 Number 4 Winter 1999.

Questions for discussion

There is no doubt that property developers in the 20th century competed for the status associated with owning the world's tallest building. And the race is set to continue into the 21st century.

Year		height/m	aspect ratio
1931 Empire State Building	New York City	381	
1973 World Trade Centre	New York City	415	
1974 Sears Tower	Chicago	442	6.5
1997 Petronas Twin Towers	Kuala Lumpur	452	
proposed Jakarta Tower	Jakarta	558	

1. In the article mentioned above, a structural engineer is quoted as saying 'If you had enough real estate, you could build a building to the Moon.' Can he be right?

2. Certainly the lower stories of any building must support the weight of everything above them. The same of course is true of mountains. The rock at the base of a mountain must be able to withstand the weight of everything above. Essentially, the maximum height of mountains is limited by the ratio of the intermolecular forces holding the rock together against the force of gravity bearing down. So buildings can be no higher than the highest mountains – we could never build as far as the Moon.

3. As the Scientific American article says, the first real tests of any tall building are wind, especially in hurricanes, and earthquakes. For a building to be stable and not in danger of toppling over, it must have a base sufficiently large for its height. The ratio of base to height is called 'aspect ratio'. Since to go higher you must build from a wider base, a developer reaching for the sky needs to buy more property (which the American structural engineer referred to as 'real estate') to build on. Why can composite building structures give a better aspect ratio?

4. The effects of wind are serious for taller buildings in three ways. First, the surface area against which the wind can push grows with height. Second, windspeeds are generally greater with height. And perhaps most important, architects must design a tall building so that it sheds wind without swaying; otherwise people inside the building might get seasick! What design features can be incorporated to minimize swaying?

5. For a building to be financially viable, it must attract users – offices, shops, recreation services, perhaps a hotel or even a university. In the USA, useable floor space means the maximum distance to a window must be 50 feet. What effects can this have on building design?

6. Another crucial factor is the floor space given to lifts. Tall buildings must have lifts to take people to the floor they want, in reasonable time. The World Trade Centre,

for example, has 99 elevators. How can designers limit the number of lifts required, so that enough floor space is left for other (income-earning) uses?

7. Tall buildings are hugely expensive. Are they justified on environmental and social grounds? Or should governments prevent them being built?

You have seen

While material properties are important to building tall, there are many other factors which architects, developers and their bankers must consider. And the race to the sky is not only a matter of solving technological problems.

Files provided

nil

Getting it to work

nil.

Alternative approaches

There are many interesting ways this reading could be extended if students have appropriate background knowledge, for example:

- acceleration forces – maximum accelerations possible for lifts
- resonance - relevant practical work and theory
- the ratio of electromagnetic to gravitational forces - the maximum height of mountains can be estimated,. See for example pp 52/53, Dobson et al (1997), Physics: Collins Educational

Social and Human context

This resource indicates one way of bridging the span between technological and social problem-solving. It should encourage proto-engineers to take a wider view of factors affecting what is possible in our built environment.

Safety

nil