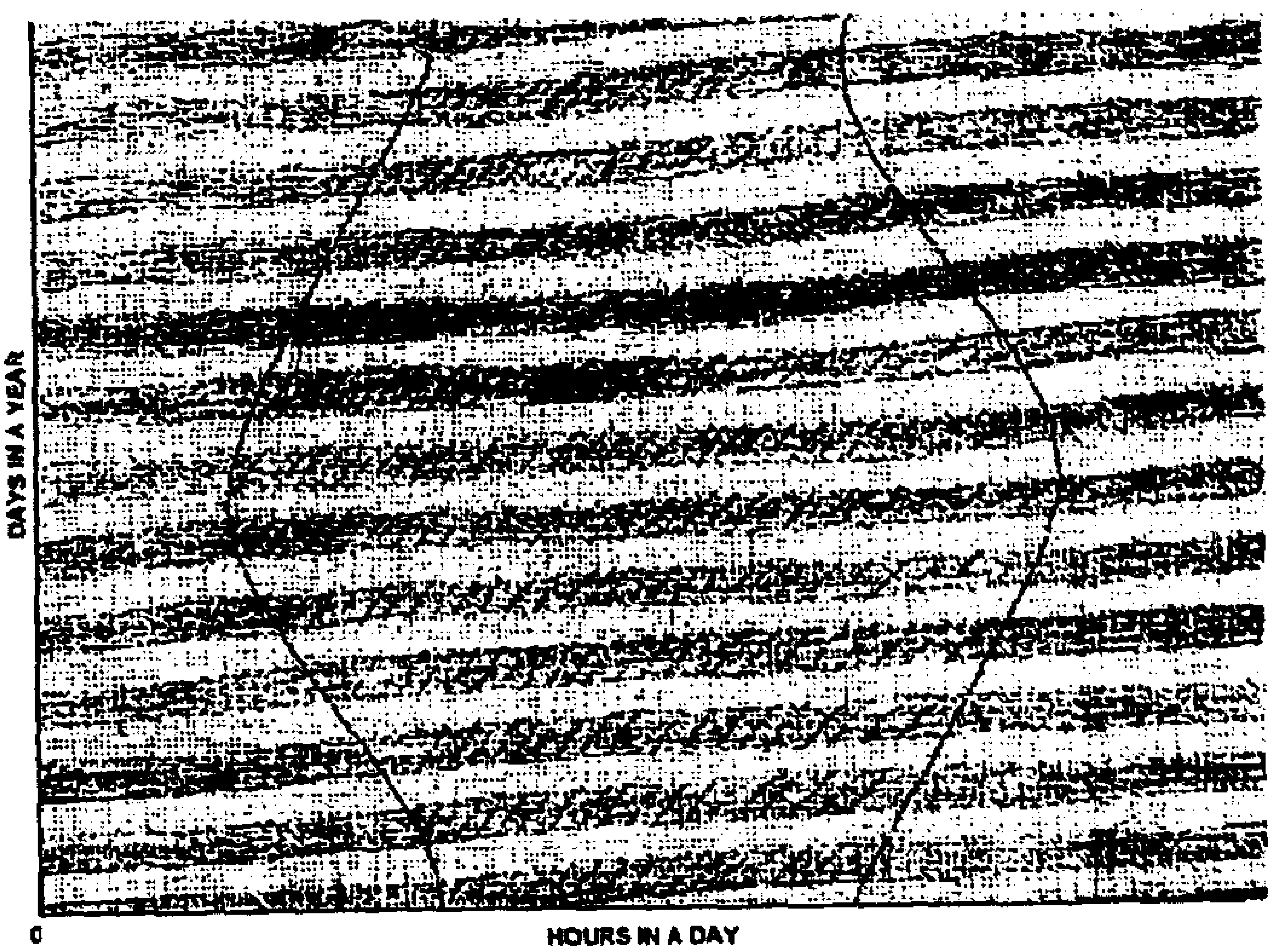


Fig.31 The result – the vertical curve stands for the ranges of visibility of the Sun, the horizontal curves for the Moon's ones

Problem No.17 – Straw

This problem belongs to the most interesting, but most difficult ones of the tournament. The question may be very important in real life, but it's really difficult to solve it in the exact terms of the physics.

First of all, there's a question of defining a "safe fall". We understand that only a fall which doesn't cause any injuries can be called "safe", but what physical qualiies are related to it? We did a lot of research in medicine, biophysics etc. and finally we found an old Czechoslovak norm for rescue-nets, which says that maximum dynamical force acting on one's body should not exceed 10 kN. We took this as a basis for our further work.

In order to express some fundamental physical properties of straw, we got some samples and did several experiments. It's obvious that the straw is compressed under an outer force in some way, resisting this force and effectively slowing down any motion. When the force (pressing down on the straw) is small, it s not difficult to find out the relation of the contraction to the pressure (it's obvious that the contraction doesn't depend on the area of the straw used). We found out soon that the results can be expressed in the form $s = hc(1 - e^{bp})$ where "s" is the contraction, "h" original height of the straw, "c" is the coefficient of maximum contraction and "b" another coefficient of the "rigidity" of the straw. We found approximate values $c = 0{,}85$; $b = 3{,}4.10^{-4}$ Pa^{-1} using experimetal means. This formula is quite accurate under realistic conditions.

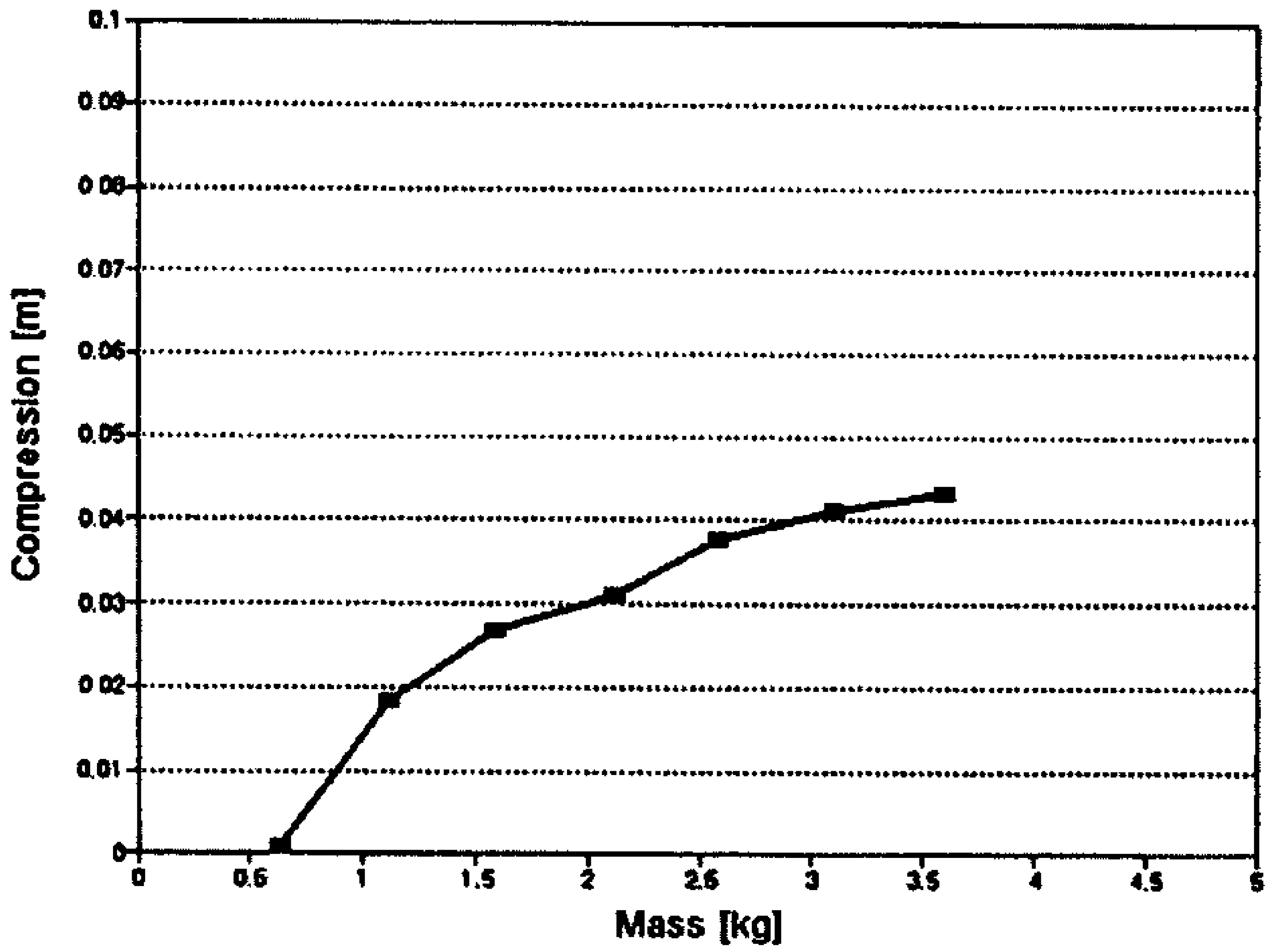
As the straw acts with a force on the falling body, it absorbs energy. If one is to fall safely, all his/her energy must be absorbed by the straw (some remnants, equivalent to a fall from the height of several centimeters, can be neglected), while the retarding force must remain within given limitations. This is

$W = \int_0^{s_m} F \, ds$, where s_m is the compression of the straw under the pressure appropriate to the force $F_m = 10$ kN, the human body having area about $S = 0{,}64$ m^2. Having expressed the relation of "p" to "s" and having integrated the resulting formula, we finally get

$$W = hc\{ S[1 - \exp(-bF_m/S)]/b - F_m \exp(-bF_m/S)\} = h \, \text{const} =$$
$$= h \, 1550 \, \text{J} \, . \, \text{m}^{-1} = hK$$

This work must be equal to the kinetic energy of the falling body, which is of course equal to $E_p = mgH$, where "H" is the height above the straw from which one falls (again, the air resistance can be ignored). Since $W = E_p$, there is $H = hK/(mg) = h \, 2{,}1$.

The answer to our problem is: If a safe fall is to be guaranteed, one meter of straw should be laid for each 2,1 meters of free fall.



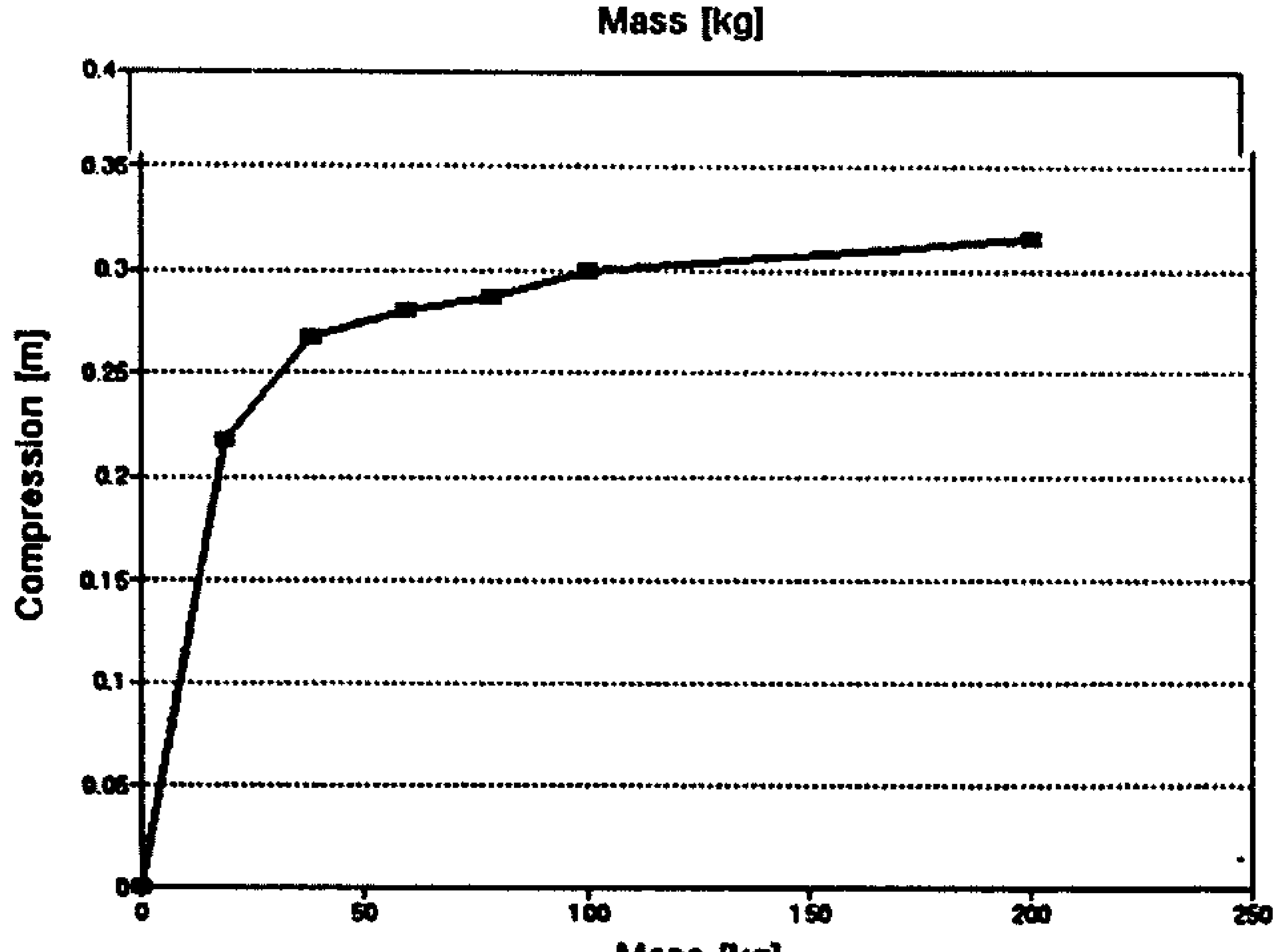


Fig.32(a,b) The compression of straw, relative to mass (both for smaller (a) and greater (b) compressing forces)