Investigation of Compacting and Adhesion of Plastic Materials on a Vertical Plane by Means of Vibration

Merab A. Chelidze, Victor S. Zviadauri, George I. Tumanishvili.

Abstract. On the base of analysis of scientific literature and realized experimental investigation of vibrations used for increasing density of the wall covering plaster materials as well as join ability to the vertical plane is presented in the paper. The grains relative displacements at the compaction of loose and plastic materials are analyzed. On the base of bio-mechanic modeling penetration of dangerous vibration in the body of operator is studied and the methods of its overcome are shown.

Keywords: amplitudes and frequency, compaction, modeling, plastering, vibration.

I. INTRODUCTION

Under action of the vibrations on loose mass the separate grains gains the quality of the motion (pseudo loose-liquid condition), which is conditioned by intensities of vibrations. At the pseudo liquid condition the traction between separate particles of the loose material is weakened, they approach to each other. So it is reached tighter placement of grains that is to say the loose mass is compacted. Maximum compaction is reached when the speedup of the amplitudes of the fluctuations are close to acceleration of free fall body. When speedup amplitudes exceed speedup of the free fall, process of compaction is broken and loose mass moves over to condition of vibration-boiling. The loose mass gains ability of mobility and pseudo fluidity.

II. SYSTEM DESCRIPTION

Not only amplitudes and frequency of acting vibration has a great influence on a process of compaction of loose and plastic materials but its direction has a great importance [1]. That is to say the vibration acts on a direction of a gravitation force or against it.

Indeed, at the acting on a material which are to be compacted by the vibrating organ from the bottom (against gravitation force), the separate grains by means of inertia are displaced downwards and they are being compacted in a lower layers. Accordingly, when on the grains are acted forces, jointly, caused by speedup of gravitation and vibrating organ the compaction of materials begins from the lower layers. When the vibrating organ is acting from a top on a material to be compacted (on grains are acted only speedup of vibration) the grains tighter placements begin in upper layers. That is to say the process of compaction begins from the top layers

The process of transporting and compaction of materials realized by means of vibration is very complex [2,3] and its full-fledged theoretical description practically is impossible. So the existing mathematical models which are describing above said processes are very far from the reality. In the course of study of processes of compacting were revealed processes which aren't described and known in the scientific literature. For example, ^in the course of study of compacting and transporting of loose and plastic materials, the motion of the bottle which was full by sand, first was slowed, then stopped and after (on measure of sand compaction) it began to move in a backward direction, while the other subjects continued moving to the direction of acting vibration, including the glass bottle filled by sand. It should be noted that the bottom of vibratory working organ was very rigid and there was no possibility for exciting of proper resonance amplitudes [4].

The process of sand compacting, which occurred in a plastic transparent bottle installed on a vibratory organ, began in lower layers (directly at vibration source) and was gradually penetrated towards upper layer. So the process of vibro-compacting is a function of time. Generally, process of compacting occurred in the several stages. Usually, after first compacting of sand there occurred other compacting processes of a little intensity.

Fig.1a. Full bottle before compaction

Fig.1b. Full bottle after compaction

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Merab A. Chelidze is with the LEPL R. Dvali Institute of Machine Mechanics, Mindeli str. 10, Tbilisi, 0186, Georgia, (phone: 899 92 95 44; fax: (+095 32) 32 39 56, (e-mail: merabchelidze@yahoo.com).

Victor S. Zviadauri is with the LEPL R. Dvali Institute of Machine Mechanics, Tbilisi, 0186, Georgia, (phone: 897 00 95 77; fax: (+095 32) 32 39 56, (e-mail: v.zviadauri@yahoo.com).

George I. Tumanishvili is with the Georgian Technical University (Tbilisi), Georgia, (phone: 897 00 20 73; fax: (+095 32) 32 39 56 (e-mail: gtumanishvili@yahoo.com).

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Fig.1a shows the full bottle with wet sand, before compaction. Fig.2 after compaction, the liquid is separated from the sand.

In spite of nature of deep damping of amplitudes in material differs from nature of damping of free fluctuations [5,6,8], even so there is a possibility (by means of curve of damping amplitudes) to define the factor and rate of the damping in a depth of the material fig. 2,3.

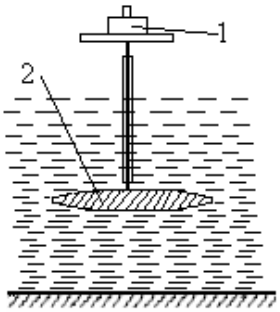

Fig. 2. 1- vibro-sensor
2-vibro-receive flange

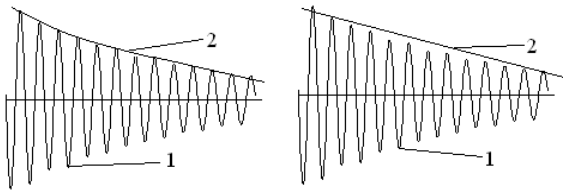

Fig. 3. 1-Damping amplitudes,
2- Curve of damping amplitudes

The bigger fluctuation of amplitudes the bigger the rates of damping of amplitudes are. Naturally, the rate of the damping of the penetrating amplitudes depends on physic-mechanical characteristic of the material - however for many plastic materials, in principle, their divergences are insignificant. Consequently, there is possibility to define penetration of vibration in depth of the material by means of simple calculation. The experience shows, that for many tasks the approximate determination of the depth of the compaction and creation of mathematical models, describing dynamics of the processes in depth of the material is enough

Practically, for many dynamic calculations it is enough to determine approximately depth of vibro-penetration. The admission that the curve of damping amplitudes is linear function, gives possibility to define very simply the depth of penetration of vibrations in material by means of the following expression

$$s=k_1 \bullet s_1/k_2 \bullet A_\phi \qquad (1)$$

where k_1-factor of a value of compaction of the material, k_2-factor of moisture changing elasticity of the material, s_1-certain length of the compacted material, $A = A_1 - A_2$ - value of difference of amplitudes at beginning and ending of length s_1, for instance 1000 cycles of 50Htz frequency to vibrations is corresponding s=20 seconds. If required more exact determination of the value of the penetration of vibrations there is possibility to define it through logarithmic decrement

$$\delta=\ln(A_1/A_2) \qquad (2)$$

Above mentioned process of dynamics of compactions is very important, particularly, when the liquid coating layer is inflicted on a vertical plane (on a wall). That is to say, when the angle between direction of acting vibration and gravity forces is a right angle, the process of compacting and inter-acting of separate grains on a vertical plane occurred very unusually. Naturally, the materials which were compacted on a vertical plane to stay further on a vertical plane must have same stick and stickiness. Otherwise, after removal of vibratory head the compacting materials will be torn away from the wall. The gravity force tries to tear away from the wall at not well consolidated layer of the covering. It is clear that, after removing vibratory head, the compacted loose materials will not stay on a vertical plane.

On the base of carried out experiments may be said that, when plastering materials layer (which is to be joined to vertical plane) do not exceed 10-15 mm, the compacting process are continued successfully on all ranges of 20-50 Hz and 0,5-4 mm of amplitudes.

However, from the practice experience is known that generated amplitudes, above 0.5 mm, in a range of frequencies 30-50 Hz, are very dangerous and their prevention is very important for working personal.

Aforesaid problem is particularly important when for the realization of technologic operation the intensive vibration is necessary and the operator executing this process is subjected to vibration in a long-continued time. Unfortunately the insulating devises and methods protecting operators from acting of dangerous vibration are not effective in many cases.

In spite of the fact that modern drilling, polishing and cutting tools are balanced on a high level, however they become sources of generating dangerous vibrations at the performing of technologic operations. The source, of vibration in such cases is heterogeneity of processing surface or material and operator's changeable pressing on the device and displacement motions. Moreover, the muscle tension, caused by holding a heavy subject in a hand, is increasing tremors [7]. For its part the tremor become reason of changeable acting on the noted devices. Noted phenomena depends on time functionally, that is to say with tire of an operator is increased nonlinearly. It must be to note that process of tiring of an operator is running more sharply at the acting vibration than holding only heavy subjects in a hand. At the acting vibration in a long period of time hallucinations or so called vibration inebriety (intoxication) may be occurred [1, 2].

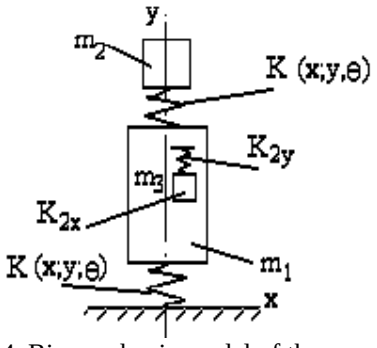

Fig.4. Bio-mechanic model of the operator

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For investigation of noted problems, by viewpoint of bio-mechanics, mathematical model of a load-operator was created where kinematical scheme shown on fig. 4 have been taken into account. For instance the mathematical model of human body with three masses (body m_1, head m_2 and belly m_3) is considered as a mathematical system with eight degree of freedom and with eight differential equations as minimum.

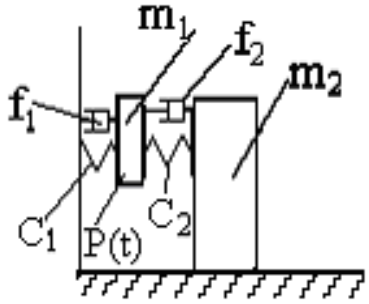

Fig.5. Simplified bio-mechanic model

Complexity of describing mathematically the real object (human body), in many cases, compels us to apply comparatively simplified models. On the given stage the goal of our investigation was to define a level of transferred vibration from vibro-head to an operator, but not to determine the depth of vibration penetration in a human body and corresponding reactions from separate organs. So for determining the transfer of vibration on a human body (hands) by the oscillating plate used for compaction of liquid concrete layer were used the following simplified differential equations (fig. 5). First equation is describes oscillations of the vibrator and second – that of hands (wrist) of the operator.

$$m_1 \frac{d^2 x_1}{dt^2} + f_1\left(\frac{dx_1}{dt} - \frac{dx_2}{dt}\right) + C_1 x_1 + C_2 (x_1 - x_2) = P(t);$$
$$m_2 \frac{d^2 x_2}{dt^2} + f_2\left(\frac{dx_2}{dt} - \frac{dx_1}{dt}\right) + C_2 (x_2 - x_1) = 0; \qquad (3)$$

Where - m_1, m_2, - are accordingly masses of the vibrator and operator, C_1, C_2, C_3- accordingly - elasticity (rigidity) of concrete, vibrator and hand (wrist) of operator, x_1-vibrator oscillation amplitude, x_2- amplitude of operator wrist, f_1, f_2 - accordingly -coefficient of damping of vibrator and operator, P(t) -driving force. At the mathematical simulation the pose of the person was considered fixed, but body itself was considered as hard deformed.

On a Fig. 6 are shown the oscillations of working vibrator 1 and of wrist 2 in a condition when operator holds vibrator freely in a hand. On Fig. 7 - is shown oscillations of working vibrator 1 and of wrist 2 when operator is pressing working vibrator by hands.

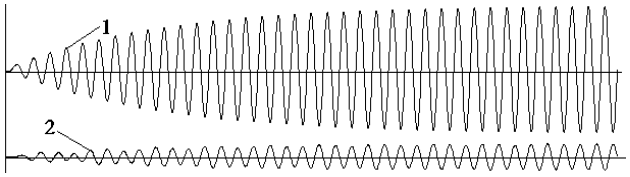

Fig.6. Oscillations: vibrator 1, wrist 2. The vibrator is held freely by operator.

The influence vibration on person depends on its spectral composition, directions, continuation of its acting, as well as on the individual particularities of the person.

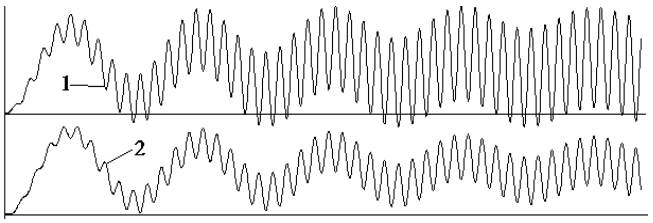

Fig.7. Oscillations: vibrator 1, wrist 2. The vibrator is pressed by operator hands.

The results obtained by us and described in numerous scientific literature show that in condition of stressed (Fig.7) muscles (in models of increased bounces) the vibration is circulated very intensively and it should be noted that the peaks of circulated amplitudes do not decrease. For human health aforesaid condition is very undesirable while the slacked (fig.6) muscle (the model of lower bounces) decreases the peaks of dynamic loads significantly. So it is very desirable and necessary that the men were released from holding the vibratory devices for a long time. When the operator presses the vibratory devices only (do not holding it in hands) by fingers it (Fig. 8) is less dangerous than holding it in the hands exercising technological operations in that condition. So, it is reasonable to create special adjustments by means of which the operator becomes free from holding the vibratory devices in hands.

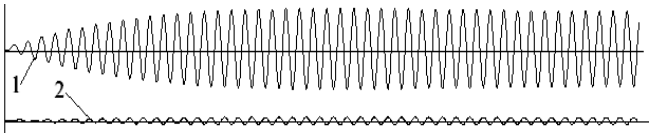

Fig.8. Oscillations: vibrator 1, wrist 2. The vibratory device is
pressed by operator's fingers.

At the experiments were observed that accordingly with changing of muscles tension, muscles elasticity as well as own resonance frequencies of different organs have been changed. The changeable range of muscles depends on many factors: physical condition, age, tiring and so on. The more are stressed the muscles the more vibration penetrates in it. So here is notable that the vibration penetrating depends on an inter-disposition of body parts.

Naturally, the operator, who holds a heavy thing in frontal opened hands, for reducing torque moment wrapped up hands and brings the load near to his chest. Unfortunately, in both cases the operators muscles are stayed in a tension condition and the fingers are entirely pressing on hands of vibrating device. On the base of realized experiments and theoretical analysis of bio-mechanic scientific literature [1,2,3,4] can be conclude that in a condition of heavy strained fingers and hands muscles the vibration are penetrated very intensively into body of operator. Vibration of high frequencies is damaging cells and lower frequencies with high intensive amplitudes can cause in separate organs resonance oscillations accompanying with a big pain. At

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coincidence of frequency of vibration with a pulse of heart may be occurred very dangerous condition for the life.

The results of researches broadly may be used for the wall surface finish (repairing) works. It may be used also in the restoration and renovation of old buildings, where big problems are observed at fixing (sticking) of the plaster materials on demiged surfaces.

III. CONCLUSION

Up to date the theory of deep compaction of the granular structure does not exist. Parameters of the vibratory deep compaction usually is selected from experience of production or from experiments carried out by different specialists. Use vibrations for processing on the wall inflicted covering are very important, as far as the moving particles remove the soft admixtures from the wall and occupy their places. Owing to above mentioned processing of covering layer by the vibration the joined surfaces of the covering with the wall becomes monolith and larger. Not compacted covering contains the ensemble of air bubbles, which reduces both hardness layer of covering and area of the joining. As the concrete easy absorbs water that becomes problematic particularly in the winter, when at frost the icy bubbles enlarges, but the concrete is being compressed, accordingly appear as destroying tension of the concrete so and the force tearing away the covering layer from the wall. Thus, from the above we can conclude that using of vibration and mechanization in the works connected with covering and facing of the walls has big perspectives in the whole world.

Various materials have different physical and mechanical characteristics; therefore for compaction of various materials the various amplitudes and frequency are needed. At the amplitudes, above 0.5 mm and 25 Hz is very important to protect the working personals from long-continued time vibration influence. For this goal it is reasonable to provide additional research work for creating special devices freeing operators from continual holding the vibratory equipments in hands.

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