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VIRTUAL PLANT DESIGN OF INDUSTRIAL MANUFACTURING SYSTEM FOR EARTH PLASTERS

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ABSTRACT

Earth plasters represent traditional building materials, which were earlier used to cover walls of buildings. These materials were replaced about one century ago by lime-cement-sand mixtures. Earth-plasters have introduced again and their excellent properties to regulate indoor humidity have been scientifically explained. The accumulation property of moisture also averages the indoor temperature by means of energy flows during the phase changes, which makes it a very popular solution to be used as indoor plaster in low energy Passive Houses. Earth (loam) plaster is a composite, in which the sand granulate is the filling material, which is glued by clay and bound by natural fibres obtained for instance from hemp. Small amounts of earth-plasters can be produced by manually controlled workshops, but larger production amounts call for a modern automated plant to manufacture the natural plaster-composites like any other industrial end-product in concrete and aggregate business. The design task of such plant by using 3D virtual design tools is described and the results are shown.

KEYWORDS

Virtual Plant Design, Earth Plaster, Traditional Building Materials

1. INTRODUCTION

Traditional building materials [1], which are not based on the use of lime and cement for solidification processes, are typically composed of sand and clay minerals. These pure toxin free natural materials are known to have a positive effect to the indoor climate quality, but they have one weakness, which is the crack formation due to the shrinkage stresses. In order to increase the tensional strength of the composite, a natural fibre component is added. The problem arising now is how to produce such composites in an industrial way so that the fractions of different minerals and fibres are in correct balance [2]. As existing plaster production technologies cannot directly be applied to the production of natural fibre plasters, a co-operation between researchers and plaster producers has been initialised to make a completely new design for a future industrial plant following a “soft production principle”. The developer team consists of designers and specialists in agriculture, soil sciences and building materials [3].

This paper shows the future production processes and the level of automation to be achieved, especially concerning sand and loam treatment from the pit to sales packages. The whole process includes such unit operations as sand and loam mining, sand sieving in pit, biological aging and pre-drying of loam, transportation to the factory, storages, loam drying, loam milling, feeding to the mixing process, mixing, weighing and packaging.

This paper includes process descriptions, 3D models, digital pictures of the production plant and individual machinery with related dimensioning theory. The presentation also highlights the performance of the VR tools (Virtual Reality) [4] in concurrent plant design.

2. TASK DESCRIPTION

A significant difference between the concrete-industry and the manufacturing of earth plasters is the volume of production and, therefore, the size of the production unit. As concrete factories are highly automated [5] with high day-production records, earth-plasters are produced rather manually in plants, where the day-production depends directly on the availability of raw materials and on the current selling demand. Because earth-plasters represent simultaneously traditional materials and green design of buildings, the end-users also expect that the production way is soft in sense that small amount of machinery with low unit power are needed in compact workshops. In fact, the reality that the production plants are owned and driven by SME's arising from the green business sector or by larger farms as a secondary business, corresponds to this figure completely. The increasing growth of the market of low-energy houses, however, calls for larger and larger amounts of natural materials, which need larger production units to fulfil the increasing market demand.

In manufacturing workshops based on manually driven batch processes this leads typically to problems:

1. How to organize the storage and feed of raw materials into mixing units.
2. How to transport materials inside the workshop.
3. How to pack and store the end product before transportation.

In the traditional workshop philosophy one then increases the size of manipulation tools instead of developing the process, which leads to the use of earth-moving machinery in indoor places. As large masses with small payloads are moved back and worth, the energy consumption and therefore also emissions are increasing to such level, which is highly against sustainable manufacturing philosophy.

The purpose is now to show, how a traditional workshop can be reorganized so, that modern production philosophies will not come to conflict with the end-users requirements to make the end-product with a minimum amount of industrial treatment. This work includes the following set of steps in the analysis and design of the plant:

1. Black-box description of the manufacturing process including the flows of raw-materials-in and end-products-out.
2. Design of the process flow diagram including the division of the complete process to a sequence of unit-processes.
3. Development of the unit processes.
4. Development of the materials handling devices to store, dose and convey the plaster components between the unit processes.
5. Lay-out-design of the plant including machinery, storing devices and conveyors following a one-directional propagation of material flow through the plant building.

The object of a case study, where a traditional workshop will be reorganized to a modern production unit, locates in the middle of agricultural environment, where the sources for the necessary plaster components also exist.

3. PROCESS DEVELOPMENT

The complete process consists of the following set of unit processes (Fig. 1):

1. Excavation of the raw materials.
2. Sieving of sand for different fractions.
3. Biological aging of clay and loam
4. Drying and milling of clay and loam
5. Storing to silos.
6. Dosing components from silos to batch feeder.
7. Feeding the batch and fibres to the mixer.
8. Mixing the batch.
9. Conveying the mixing result to packing silo.
10. Packing the plaster granular to sacks.

Manufacturing process of earth-plaster starts in a sand pit where sand is mined with excavators and wheel loaders. This is a natural source of clay, loam and soil, where different soil components are naturally layered as a consequence of geological mineral depositions.

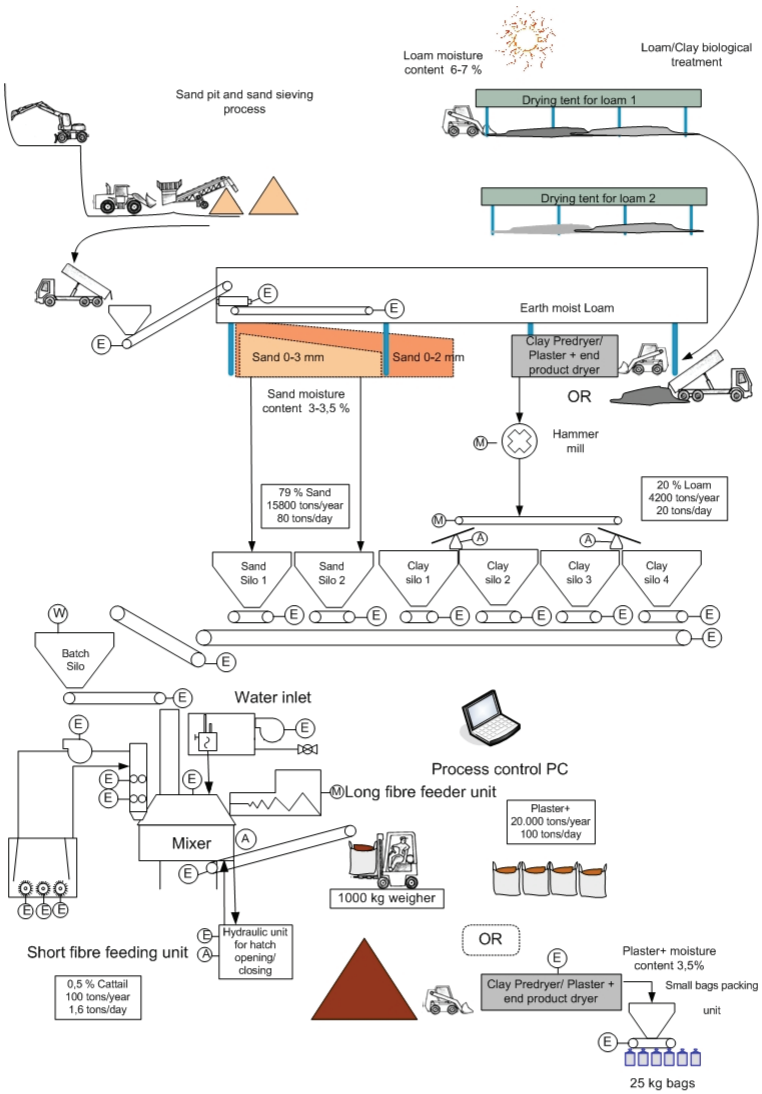

Figure 1 Process Diagram of the Earth-Plaster Production Plant

Sand is sieved to different particle sizes by screening machines already in the pit and transported to a covered storage with a capacity more than *1000 m*^{3} in *6m* high piles. For further processing the sand is filled to two *30 m*^{3} silos from which the sand can be fed and adjusted automatically to the mixing process.

Different types of clay and loam are delivered from various mines to an aging process of several months. During aging process the clay is affected by natural micro-organisms, which utilize the organic components of the soil in order to stabilize it in the end usage. After aging the material is dried and milled into finest particle size. Milled clay and loam is stored in four similar feeding silos than the sand.

Granular materials, sand and clay, are fed automatically to the mixing process from totally six similar feeding silos according the recipe of plaster in production. These materials are firstly dosed into a batch feeder and in suitable stage of process the batch feeder is emptied to the mixer.

Also fibres are fed and dosed automatically from filling chamber to the mixer. The moisture of the components is controlled by means of a set of water jets to optimise the adhesion between smaller and larger soil particles.

Mixed plaster is packed to a big bag corresponding to one ton mass of end product and the bags are handled with a fork lift truck.

4. DESIGN OF THE PLANT

After specification of the technical requirements of the plant the design started by measuring and modelling the existing facilities and machinery. After several discussions and a testing period some new unit processes were designed in principle level and the machinery were placed and replaced in an iterative process with the plant owner.

Modelling was done with Autodesk Inventor 3d program [6]. Models were converted with Autodesk 3ds Max to virtual environment [7] and studied in immersed mode by VR4Max visualisation software. With this software the designers and customers are able to study the models from inside as three dimensional visual views. When able to walk around in a virtual factory one can have a better idea of the lay-out and design.

The plant (Fig. 2) consists of the following parts, in which the corresponding unit processes are driven during the manufacturing:

1. Sand and loam storages (Fig. 2, left end).
2. Mixing department (Fig. 3).
3. Fibre feeding unit (Fig. 4).
4. Packing station (Fig. 4).

Sand and clay are stored firstly under roof on floor condition. Before mixing clay is milled by hammer mill and both sand and clay is loaded in feeding silos.

Sand, loam and clay are led to the mixing department by an underground conveyor. Fibres are fed to the process from containers waiting nearby the mixer. Materials are fed and dosed to the process computer controlled according selected program. Filling of the fibre containers and changing of full big bags are made with fork lift truck.

Fibres are sucked and blown pneumatically in closed circuit into a fibre feeding tower. From the tower the fibres are dosed to the mixer by two soft roller nips. Water jet is used to control the moisture content of the granulates during the mixing. This can be regulated to find best performance in mixing. A pan-type mixer developed from a model used in wet concrete mixing is suitable also for this low moisture application.

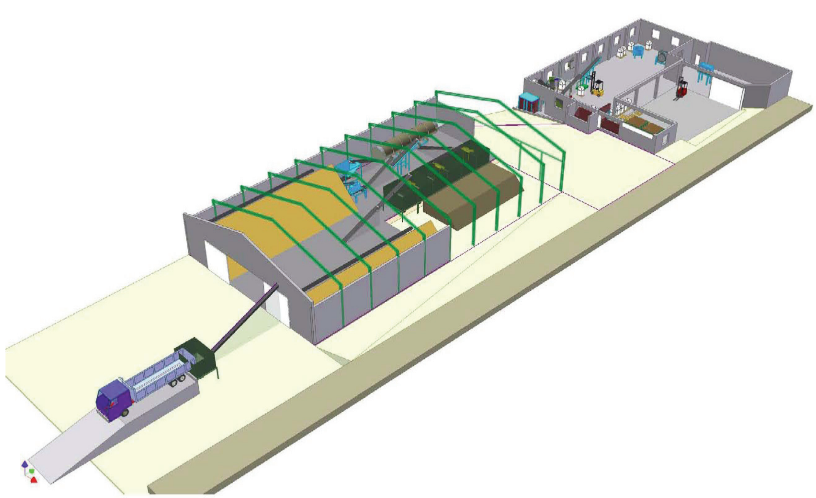

Figure 2 General Overview of Earth-Plaster Production Plant

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Figure 3 Machinery and Equipment of the Mixing Department and Packing Station

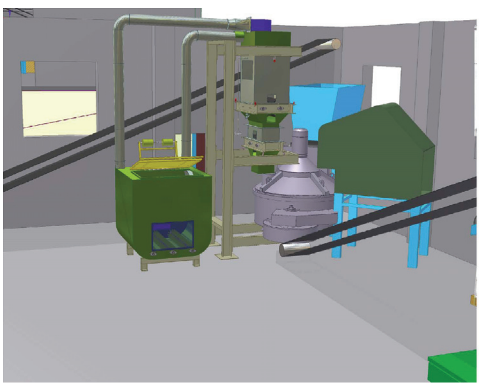

Figure 4 Mixing and Feeding Machinery of Fibres and Soil Granulates

5. CONCLUSIONS

A new factory lay-out was designed with 3d modelling tools. New design improves dramatically the storage capacity of raw materials and the automation level of the process. This design was an interactive process with the plant owners so that several different lay-outs were studied in 3d virtual environment. With visualisation software and special 3d glasses it was possible to show the lay-out design to customers inside the virtual factory. In this way one got better insight to the final plant design and longer development steps could be taken. To complete the plant design, new equipment for automatic fibre feeding were designed and placed to the process.

6. ACKNOWLEDGMENTS

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