PROTECTION OF LIVESTOCK BUILDINGS AGAINST INFILTRATION OF ANIMAL MANURE IN CONDITIONS OF WELFARE AND HYGIENE

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Abstract

In modern livestock farms, controlling the infiltration of animal manure into floors, platforms, channels and other construction surfaces is an essential condition for both environmental protection and animal welfare and maintaining the durability of buildings. Animal manure, wastewater and permanent humidity are aggressive factors that affect structures through chemical, physical and biological processes, favoring the degradation of materials, the loss of hygienic and sanitary conditions and the emergence of risks of soil and groundwater contamination.

The paper analyses the main categories of construction materials used in livestock farms, both prefabricated and in situ, with a focus on their ability to limit infiltration, withstand aggressive environments and support suitable conditions for animals. Special concretes, prefabricated reinforced concrete elements, waterproof mortars and screeds, membranes and sealing layers, epoxy and polyurethane coatings, prefabricated gratings, as well as composite construction systems are discussed. The role of heat recovery ventilation and air conditioning in humidity control, material protection and maintaining a microclimate favorable to animal welfare is also analysed.

The results highlight that the correct choice of materials and execution technologies must be made depending on the breeds housed, the operating regime, the mechanical loads and the aggressiveness of the environment, so as to simultaneously ensure hygiene, animal welfare, environmental protection and the durability of the constructions.

Key words: *livestock buildings, animal manure, infiltration, precast concrete, in situ concrete, durability, animal welfare, ventilation*

INTRODUCTION

Livestock buildings are subject to much more aggressive operating conditions than many other categories of agricultural or civil constructions [1, 2].

In animal shelters, floors, platforms, drains and surfaces in contact with manure are permanently exposed to humidity, organic matter, nitrogen compounds, ammonia, organic acids, sulphates, mechanical stress and temperature variations [3-7].

Under these conditions, the infiltration of animal manure into building materials is not just a technical problem, but one with multiple effects.

In according with [8-18] it can lead to:

• progressive degradation of concrete and structural elements;

• corrosion of reinforcement and metal components;

• contamination of the base layer and foundation soil;

• the appearance of persistent odors and an unhealthy environment;

• multiplication of pathogens;

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• increased risk of injury and discomfort for animals;

• reduced service life of buildings.

From this perspective, the correct design of constructive surfaces and the choice of appropriate materials become essential.

Modern solutions include both prefabricated and in situ materials, each category having specific advantages and limitations [19-22].

At the same time, current requirements in animal husbandry require that the materials used ensure not only resistance and tightness, but also favorable conditions for animal welfare: walking and standing comfort, moisture reduction, hygiene, easy maintenance and sanitary safety [23- 26].

MATERIAL AND METHOD

The paper was elaborated by integrating previously developed concepts regarding the impact of livestock farms on the environment, the influence of environmental factors on constructions and the interaction between the farm and the ecosystem, with an emphasis on the materials and construction solutions used to control animal manure infiltration.

The following were analyzed:

• the main sources of moisture and chemical aggression in livestock shelters;

• the effects of infiltration on buildings and the environment;

• prefabricated materials usable in areas exposed to manure;

• precast materials or applied in situ for waterproofing and protection;

• criteria for choosing constructive solutions based on animal welfare and construction durability;

• the role of ventilation and air conditioning in controlling moisture and protecting materials.

The analysis aimed to correlate engineering requirements with animal husbandry and environmental ones, in order to formulate solutions practically applicable in modern farms.

RESULTS AND DISCUSSIONS

The importance of controlling infiltration in livestock shelters

In livestock farms, animal manure is composed of solid and liquid fractions, frequently mixed with washing water, feed scraps and other organic residues [27, 28, 29].

In the absence of waterproof and chemically resistant surfaces, these mixtures penetrate the pores of materials and support layers, where they produce cumulative effects.

Infiltration control is important for several reasons:

• prevents soil and groundwater contamination;

• reduces the occurrence of gases and odors resulting from stagnation and fermentation;

• limits chemical aggression on concrete and metal;

• keeps surfaces clean and sanitizable;

• improves animal comfort and health;

• reduces maintenance and repair costs.

Without proper sealing, structures become vulnerable to carbonation, sulfate attack, biological corrosion, and accelerated mechanical degradation.

Functional requirements of materials used in areas exposed to manure

The construction materials used in livestock housing must simultaneously meet several requirements:

• very low permeability;

• chemical resistance to ammonia, organic acids, sulfates and nitrogen compounds;

• mechanical resistance to traffic and abrasion;

• stability to moisture and thermal cycles;

• easy-to-clean and disinfect surface;

• safe behavior for animals, including controlled adhesion and reduced risk of slipping;

• compatibility with manure disposal technologies.

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From an animal welfare perspective, the surface should be neither too rough, to avoid injury to limbs, nor too smooth, to avoid slipping. This condition directly influences the choice of construction system.

Precast materials used to minimize infiltration

Precast reinforced concrete elements

Precast reinforced concrete elements are widely used in livestock farms for:

- technical floors;
- collection channels;
- gutters;
- basins;
- partition walls;
- covering plates;
- elements for manure platforms.

The main advantages are:

- better quality control in manufacturing;
- superior compaction and reduced porosity;
- fast execution;
- constant geometry;
- the possibility of using special concretes, with recipes optimized for aggressive environments.

To limit infiltration, precast concrete must be made of concrete with:

- low water/cement ratio;
- waterproofing additives;
- high resistance to water penetration;
- sufficient reinforcement coverage;
- high density and low absorption.

Precast manure grates

Especially on swine and cattle farms, precast grates made of concrete or composite materials play an important role in the rapid separation of manure.

This simultaneously contributes to:

- reducing the animal's contact with the wet and dirty environment;
- improving hygiene;
- reducing the time that manure stagnates on the surface;
- limiting infiltration by controlling the path of liquids;
- protecting the substrate.

These elements must be carefully designed to ensure:

- resistance to dynamic loads;
- slot dimensions compatible with the species;
- comfort when moving;
- smooth and non-aggressive edges.

Precast panels and boards for walls and partitions

Side walls, interior partitions and low areas exposed to manure splashes can be made with precast panels treated with water repellent or additionally protected with waterproof coatings. These solutions reduce absorption and facilitate cleaning.

Materials placed in situ

Cast-in-situ concrete for floors and platforms

In-situ concrete [30, 31, 32] remains one of the most widely used solutions in livestock construction, especially for:

- continuous floors;
- manure platforms;
- basins and channels;
- ramps and technological alleys;
- foundations.

The major advantage is continuity. By correctly performing the pouring and joints, a more uniform surface can be obtained and easier to seal than with fragmented systems.

For these applications, the following are recommended:

- waterproof concrete;
- concrete with active mineral additives;
- concrete resistant to chemical attack;
- concrete with fibers, in certain situations, for cracking control.

Durability depends strongly on:

- concrete composition;
- correct vibration and compaction;
- post-cast treatment;
- correct execution of joints;
- surface protection by additional layers.

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Waterproof mortars and screeds

Special mortars and protective screeds can be applied over the concrete substrate to:

• leveling;
• waterproofing;
• increasing wear resistance;
• correcting the drainage slope;
• supporting synthetic coatings.

In areas with intense liquid action, these layers must have high adhesion to the substrate and good chemical resistance.

Membranes and sealing systems

To reduce infiltration, especially in basins, channels, storage platforms and collection areas, in situ applied membranes can be used:

• special bituminous membranes;
• polyurethane membranes;
• epoxy membranes;
• membranes based on PVC or other synthetic materials.

These systems have the advantage of creating a continuous barrier against liquid penetration, provided they are correctly applied and protected against perforation.

Epoxy and polyurethane coatings

These coatings are frequently used for the protection of concrete surfaces exposed to aggressive environments [33, 34].

They offer:

• high tightness;
• good chemical resistance;
• easy cleaning;
• reduced absorption;
• efficient sanitation.

Depending on the formulation, the surface can be adapted to achieve a certain level of roughness compatible with animal movement.

Correlating materials with animal welfare

The materials used in shelters cannot be chosen solely based on criteria of strength and tightness.

These directly influence the well-being of the animals through:

• the moisture level of the surface;
• comfort when standing and moving;
• the risk of injuries to limbs and hooves;
• contact temperature;
• the cleanliness and microbiological load of the shelter.

For cattle, for example, floors must combine resistance to manure with a texture that reduces slipping and locomotor stress.

For swines, grates and resting areas must reduce excessive moisture and limit the accumulation of manure. For poultry, humidity control and ease of sanitation are priorities.

Therefore, the optimal solution is usually a composite one:

• resistant load-bearing layer;
• waterproof protective layer;
• finish adapted to the species and exploitation technology.

Durability of materials in aggressive husbandry environment

The livestock environment accelerates the degradation of materials through the simultaneous action of:

• permanent moisture;
• ammonia;
• organic acids;
• sulfur and nitrogen compounds;
• abrasion;
• mechanical pressures;
• temperature variations.

Under these conditions, insufficiently protected materials develop:

• cracks;
• peeling;
• efflorescence;
• material loss;
• corrosion of reinforcements;
• decreased sanitation capacity.

Durability is achieved by combining:

• correct design;
• choosing the right material;
• quality execution;
• regular maintenance;
• monitoring degradation.

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Recommended construction solutions

In practice, to minimize infiltration and increase durability, the following are recommended:

• platforms and floors made of waterproof concrete with controlled joints;

• dense precast for channels and gutters;

• prefabricated gratings adapted to the breeds;

• superficial protection with resins or membranes in very aggressive areas;

• correct slopes for rapid evacuation of liquids;

• collection systems that reduce stagnation of manure;

• early repairs of cracks and surface defects;

• separation of wet areas from animal resting areas.

The role of heat recovery ventilation and air conditioning in reducing infiltration, animal welfare and building sustainability

In modern livestock farms, the performance of building materials does not depend exclusively on their nature and quality, but also on the indoor microclimate conditions in which they operate. Excessive humidity, condensation, the accumulation of aggressive gases and large temperature variations accelerate the degradation of floors, surfaces in contact with manure, structural elements and protective systems applied over them.

In this context, controlled ventilation [35, 36, 37, 38, 39], heat recovery ventilation [40, 41, 42, 43, 44, 45] and, in certain situations, air conditioning [46, 47, 48, 49, 50, 51, 52] contribute directly to both animal welfare and building sustainability.

In livestock shelters, animals constantly release heat, water vapor, and gases resulting from respiration and the fermentation of manure. This continuous input favors the increase in relative air humidity and the formation of condensation on cold surfaces.

If moisture evacuation is not carried out efficiently, building materials absorb water, increase their apparent permeability, become more vulnerable to chemical and biological attack and gradually reduce their operational capacity. In addition, persistent moisture keeps surfaces dirty for longer, favors the infiltration of the liquid fraction of manure and worsens hygiene conditions.

Heat recovery ventilation is a modern solution through which stale air is exhausted and the fresh air taken in takes over some of the thermal energy of the exhausted air. In the cold season, this solution allows maintaining a favorable indoor climate without excessive energy losses.

The importance of this technology in animal husbandry is twofold. On the one hand, it helps maintain temperature and humidity within optimal limits for the housed species, reducing thermal stress, condensation and the risk of disease. On the other hand, it limits the deposition of water vapor on construction surfaces and reduces the duration of exposure of concrete, coatings and metal elements to aggressive moisture.

By controlling humidity, effective ventilation indirectly reduces infiltration. A floor or platform kept drier will be less susceptible to the penetration of the liquid fraction of manure through microcracks, pores or degraded joints. Also, reducing moisture stagnation limits accelerated carbonation processes, sulfate attack, reinforcement corrosion and alteration of protective layers applied to the surface.

Air conditioning systems, used especially in special husbandry spaces, in shelters with strict microclimate control or in sensitive sectors such as maternity, nursery or certain poultry spaces, play an important role in controlling temperature and humidity.

These systems contribute to maintaining a stable thermohygrometric regime, reducing heat stress on animals and limiting variations that affect both biological comfort and the behavior of building materials.

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Excessive temperature favors the intensification of manure fermentation and increased ammonia emissions, while high humidity accelerates corrosion and surface degradation processes.

Therefore, controlled climate control can play an indirect role in protecting the building.

The correlation between ventilation, air conditioning and building materials is particularly important in the case of waterproofed surfaces, resin-treated floors, precasted grates and manure collection areas.

Even though these materials are designed to withstand aggressive environments, their lifespan decreases significantly when operating in conditions of excessive moisture, repeated condensation, and accumulation of corrosive gases.

Therefore, their actual performance depends on the existence of an adequate ventilation and climate control system.

From an animal welfare perspective, maintaining an optimal microclimate means:

• reducing thermal stress;

• decreasing the incidence of respiratory diseases;

• limiting contact with wet and dirty surfaces;

• improving comfort during rest and movement;

• maintaining a better general state of health and productivity.

From a construction perspective, the same measures mean:

• reducing moisture absorbed by materials;

• limiting condensation on surfaces and in joints;

• reducing chemical and biological aggression;

• protecting finishes and waterproofing layers;

• increasing the service life of floors, platforms and structural elements.

In conclusion, heat recovery ventilation and air conditioning systems should not be viewed only as equipment for biological comfort, but as constructive and functional elements integrated into the strategy for protecting materials and minimizing infiltration in modern livestock farms.

The efficiency of prefabricated and in situ materials is significantly increased when they operate in a controlled microclimate, with temperature and humidity maintained within optimal limits.

CONCLUSIONS

In modern livestock farms, the infiltration of animal manure into construction surfaces is one of the main causes of material degradation and damage to hygiene, animal welfare and environmental protection conditions.

Limiting this phenomenon must be approached through an integrated strategy, in which prefabricated and in situ materials are selected and combined according to the specific requirements of each farm.

Precast elements offer important advantages through quality control, high density and speed of execution, while in situ solutions allow for continuity, adaptability and the creation of complex waterproof surfaces.

The correct choice of these materials must simultaneously aim for imperviousness, chemical and mechanical resistance, ease of sanitation and compatibility with animal welfare.

Heat recovery ventilation and air conditioning systems complement these constructive solutions by controlling humidity and indoor temperature, contributing both to the health and comfort of the animals and to protecting materials against premature degradation.

In this way, the technical performance of the construction and the quality of the indoor environment for animals must be treated as a unit, as complementary objectives of modern and responsible animal husbandry.

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