ISSN 1682-8356
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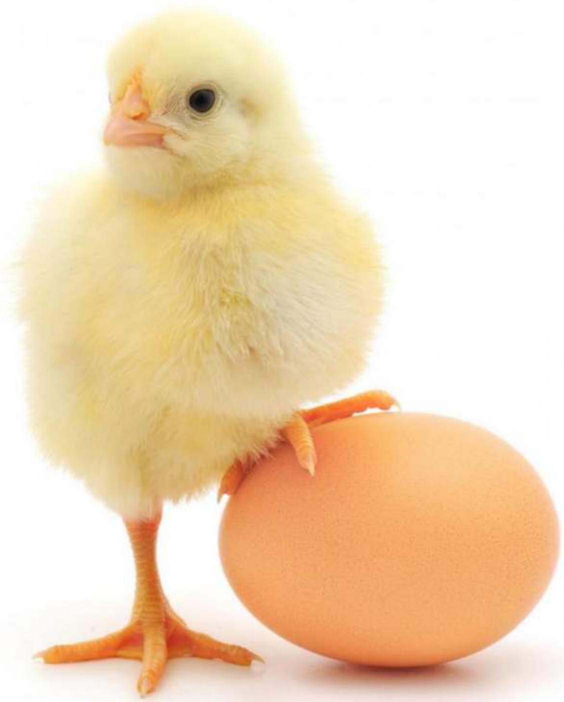

# INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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International Journal of Poultry Science 5 (10): 921-926, 2006
ISSN 1682-8356


# Economical Supporting System Design for Laying Hen Poultry Houses

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**Abstract:** Poultry houses should be economical and should demonstrate adequate resistance and safety. In poultry houses, generally truss systems or frames are used as the supporting systems and reinforced concrete and steel sections are used as construction materials. In this study, 45 poultry houses from 25 commercial enterprises within the study area were selected as the material. They were evaluated based on their capacities, system designs and construction material used in their supporting system. Initially, construction materials selected for supporting systems and their dimensions were determined and their structural sufficiencies were evaluated. Then, seven model poultry house were developed by taking the current conditions of the enterprises and related literatures into consideration. Three different material combinations were considered for supporting system of each model developed: Steel truss - reinforced concrete column, steel truss – steel column and frame system. Thus, total of 21 different combinations for 7 models were evaluated. Depending on supporting system characteristics, load analysis and statical calculations were carried out for each model and supporting systems were dimensioned based on results obtained from statical solutions and economical comparisons were carried out among them. It is believed that results of this study may contribute significant perspectives for the project engineers in poultry housing systems.

**Key words:** Poultry houses, truss systems, project engineers in poultry housing, cost analysis

## Introduction

Various facilities and installations are required in poultry enterprises for proper system operation. Some of these facilities are poultry houses, incubators, egg storages, marketing units, vaccination units, feed storages, equipment and machinery storages. Egg storages, feed storages, vaccination units, equipment and machinery storages may either be designed under the same roof with poultry houses or they may be designed as separate units depending on enterprise capacities. Poultry houses have a special significance among these units since the production materials are housed in them and they are directly related to production activities. That is why, besides providing the best conditions for production activities, they should also be economical and should demonstrate adequate resistance and safety.

Larger part of the investment in poultry enterprises is allocated for the construction of housing system. Elimination of errors and mistakes made in design phase of poultry houses is difficult to overcome during the latter phases and it also requires additional investments. When the correct and proper systems are designed and constructed, investment return period is shortened and facility operational success rates increase.

In Turkey, studies on problems arisen in poultry houses revealed that structural problems related to construction materials constituted larger part of these problems (Ekmekyapar, 1988; Öztürk and Olgun, 1993; Olgun, 1997). In recent years, there is a significant increase in the number of specialized enterprises in Turkey. That is why, construction of large span poultry houses and economical structural systems were brought into seen as the critical issues. However, especially the supporting systems constitute the large part of the constructional costs. Older poultry houses in Turkey are generally built-up masonry style housings but the new ones are usually framed-type. In framed types, truss beam-column combination and frames are common and steel sections are used as construction material. Especaily in large-span buildings, steel trusses and steel or reinforced concrete frames provides significant economical and safety advantages. Frame system also allows passing large spans without using columns.

Objectives of this study are to determine the supporting system characteristics and implementation problems in commercial poultry houses within the boundaries of

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Ankara, to apply computer-aided supporting system design for poultry houses with different styles and capacities and to select the most economical ones among the proposed models. The results of the study may also be utilized for the similar type of housings rather than poultry houses.

## Materials and Methods

In this study, 45 laying hen poultry houses with different design styles and capacities from 27 commercial enterprises in Ankara were selected as the material Laying hens constitute 21% of total animal inventory of Ankara Province. Poultry inventory of the province has tripled during the last decade. Significant developments were achieved in poultry sector and number of specialized large-capacity enterprises has increased day-by-day.

Method of the study consists of three phases: enterprise selection and survey form preparation, field works and office studies.

Depending of field work results, current conditions of poultry enterprises, related literature and the recommendation of poultry equipment and construction material manufacturers in Turkey, seven model poultry houses were developed. Initially two-dimensional design was carried out based on different design systems and inner-facility details and facility widths, side wall and ridge heights were determined. Then, the third dimension was calculated for different capacities and total areas and peripheral lengths of walls, roofs, doors, windows and slabs were determined for each model. To determine the areas, side wall heights were taken as 2.75 m and 3.25 m and roof slope was taken as 18º (Önes and Olgun 1989). Total window area was taken as 1/20 of the floor area (Balaban and Sen, 1988) and the clearance between window upper side and fringe was taken as 0.90 m to prevent the solar effects during summer months and fringe width was taken as 0.50 m (Olgun, 1997). Doors were placed at the ends of service alleys.

Cage dimensions were determined as 480x410x470 mm for battery type cages and 480x450x450 mm for California type cages depending on the recommendation of poultry equipment manufacturers in Turkey and assuming to place 5 hens into one cage. A 1.20 m wide service alley is left between the cage blocks and a 1.00 m wide service alley is left between the side wall and cage blocks (Öztürk and Olgun, 1993). Also two 1.80 m wide pass-ways were left at the end of cage lines. For the poultry house floor area calculation, 0.053 $m^2$ area per hen was considered for battery type cages and 0.075 $m^2$ area per hen was considered for California type cages (Maton *et al.*, 1985, Anonymous, 1993). A model system for get-away cage system was also developed since it is used in countries with developed poultry sector. Cage dimensions for get-away system was taken as 1000x960x800 assuming to place 16 hens into each cage and 0.075 $m^2$ floor area per hen (Wegner, 1990).

Following the determination of poultry house dimensions, material selection for structural members was carried out. Generally, commonly used and locally available materials were tried to be selected. Initially, required total heat conduction coefficients for walls and roof were calculated based on environmental conditions to be controlled and proper materials were proposed. While calculating the total heat conduction coefficients, 4 heat conduction coefficients were taken into consideration for the walls and 252 different alternatives were created and then total heat conduction coefficients to be provided for roof were calculated by separate heat balance calculations. Finally, heat conduction coefficients for walls were taken as 0.63, 0.75, 1.38, and 2.08 Kcal/$m^{2o}$Ch by taking the heat conduction coefficients of the most commonly used hollow bricks and briquettes and windows were assumed to be single glazed with metal frames and doors were assumed to be metal.

Calculations for the environmental control parameter were carried out based on principles defined in Anonymous (1984), Bengtsson and Whitaker (1986), Anonymous (1993) and Olgun (1997). Psychometric characteristics of air-water vapor mixture were determined from the psictometric diagrams given in Hellickson and Walker (1983) and from the computer software called Plus prepared by Albright (1990).

Following the environmental control parameter calculations, constructional details were determined. During the field works, it was seen that most of the evaluated poultry houses were framed-typed with truss-column combination supporting system. Steel trusses and concrete columns were the common construction material for them. On the other hand, frame-systems were considered as more economical and safer systems for large-span poultry houses. That is why; all the alternative models developed in this study had the combination of steel truss - reinforced concrete column, steel truss – steel column, and frame system. A total of 7 model designs with 21 different combinations were taken into consideration and statical calculations were carried out for each alternative.

Initially, load analyses were performed for each alternative. Manufacturer firm catalogues and principles specified in Deren (1984), Anonymous (1987) and Öztürk (1989) were used to determine the static dead loads of the construction materials and dynamic loads during the load analyses. Snow load was assumed to be 75 kg/$m^2$ and wind load for housing heights less than 8 m was assumed to be 50 kg/$m^2$ and axial span of load bearing systems was assumed to be 4.80 m.

Purlins were designed based on Anonymous (1985) and Uzakgören *et al.* (1985) and calculated loads.

Initially, manufacturer firm catalogues were evaluated for insulated asbestos cement plate and insulated aluminum plate dimensions and depending on these dimensions, technical characteristics such as recommended purlin spans, overlap rates and covering area were determined. Depending on the values recommended by the manufacturer firms, a ridge purlin, an eave purlin and a purlin at each node point of truss were assumed to be placed. Covering material dimensions and purlin span were selected as 220x92 cm and 1.025 m, respectively for 1, 2 and 6 numbered models; 125x92 cm and 1.100 m, respectively for 3, 5 and 7 numbered models; 250x92 cm and 1.175 m for 4 numbered model. Following the selection of these values, purlin design was performed. Three different methods were followed in purlin design. In the first method, purlins were assumed to be not tied from their mid points, in the second one purlins were assumed to be tied at their mid points (L/2) and in the third one purlins were assumed to be constructed as at least three span continuous beam (Uzakgören *et al.*, 1985).

Following determination of purlin cross-sections, truss and frame system statical analyses were performed by using SAP 90 computer software (Habibullah and Wilson, 1995).

Then, roof members and other supporting system components were dimensioned based on principles specified in Ulug and ve Odabasi (1983); Anonymous (1985); Odabasi (1985); Uzakgören *et al.* (1989); Aka *et al.* (1990), earthquake regulations for earthquake zones (Anonymous, 1999).

Following the statical solutions and dimensioning, footage and cost analysis were carried out for poultry houses based on the principles specified in Özturan (1985) and Anonymous (2004) and economical analysis were performed for poultry housing systems under various conditions.

Foundation and base plans, cross-sectional details and other detailed drawings for poultry hosing systems developed for the Province of Ankara were carried out by using Autocad 2005 software.

## Results and Discussion

All of the investigated poultry houses were designed in truss-column combination system with California cage system and 11 of them were double-story and the rest were single-story poultry houses. Lower story heights of two-story poultry houses were between 2.20-2.50 m. and this story was used as waste storage. Residence of 56% of enterprise owners or handlers was designed attached to poultry houses.

Roofs were designed with double slopes in all poultry houses and they were in winged type in 3 of them and the others were gable type. Roof slopes were between 12-26°. When the roof slopes of 17-23° recommended by Önes and Olgun (1989) for livestock and poultry houses under Turkish conditions are compared with these values, it was seen that 18 poultry houses had a slope of lower than 17°.

Eave widths of poultry houses in research area were between 0.30-0.50 m. Eave widths of 29 poultry houses were less than 0.50 m recommended by Olgun (1997). Eave widths and the clearance between eave and window lower level are the critical values for poultry houses for natural ventilation.

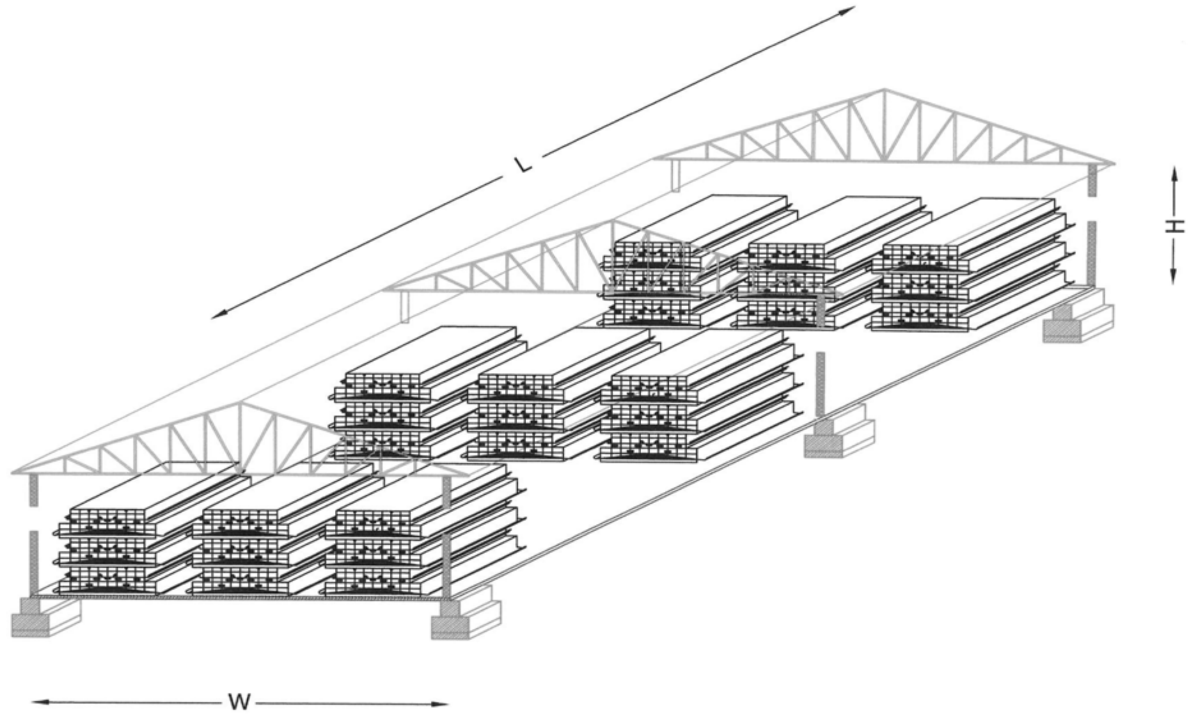
Roof trusses were Howe type in 16 poultry houses, King type in 2 of them, Pratt type in 1 of them and Fink type in 1 of them. Other 25 poultry houses have different types of trusses rather than the well-known ones. Enterprise owners have stated that they had seen and analyzed the previously constructed poultry houses and they had their roofs constructed in the same fashion by the same companies.

Upper chords of all ruff trusses were parallel to roof slopes and lower chords were constructed horizontally. There was honeycomb style roof truss in only one of the poultry houses.

Roof trusses of 32 poultry houses were fully made of steel sections, wood and steel sections were used in 8 of them and 5 of them were fully made of wood members. Steel trusses were usually made of L, U or I sections and wood trusses were made of squire, rectangular or circular cross-section wood members. In trusses with both steel sections and wood members, only the purlins were made of wood.

Truss spans were less than 2.75 m in 9 poultry houses, between 2.75-3.00 m in 26 of them and larger than 3.75 m in 10 of them. Truss spans were larger than 3.00 m in recently constructed large capacity ones. Roof trusses rest on 50x100 mm I-section in 3 poultry houses, on two 50x50 I-sections in 1 of them and the others rest on reinforced concrete columns. Reinforced concrete column dimensions were 20x30 cm, 20x20 cm, 20x40 cm, 30x40 cm, 30x50 cm and 40x50 cm for single story poultry houses. Columns dimensions for double story poultry houses were 20x30 cm in both stories of 7 poultry houses, 20x40 cm in both stories of 3 poultry houses and 30x50 cm in lower story and 20x30 cm in upper story of 1 poultry house. Column spacing was half of the truss spacing in 7 of them and equal to truss spacing in the others. Unnecessarily larger column dimensions both cause space losses and obstructs the inner functionality.

Seven model poultry houses were developed for Ankara conditions by taking the capacity and design systems of the poultry houses, related literatures and recommendations of poultry house equipment and construction material manufacturers into consideration and architectural and engineering projects of these models were prepared. Capacity and design system characteristics of these seven models were given in Fig. 1.




| Model No | Poultry capacity | Planning system | W, m | L, m* | Surround, m | H, m | Construction component's surface area, m² | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Floor | Roof | Wall | Window | Door |
| 1 | 5000 | Battery cage, 3 floors - 3 blocks | 9.5 | 38.65 | 87 | 2,75 | 302 | 372 | 232 | 16 | 6 |
| 2 | 5000 | California type cage, 3 floors- 2 blocks | 7.8 | 57.85 | 112 | 2,75 | 349 | 441 | 295 | 18 | 6 |
| 3 | 10000 | Battery cage, 3 floors - 4 blocks | 12.3 | 57.85 | 121 | 2,75 | 564 | 668 | 323 | 28 | 6 |
| 4 | 10000 | California type cage, 3 floors, 3 blocks | 11 | 67.45 | 138 | 2,75 | 605 | 725 | 362 | 30 | 6 |
| 5 | 10000 | Get-away cage, 2 floors, 3 blocks | 14.2 | 67.45 | 143 | 2,75 | 786 | 1007 | 354 | 36 | 6 |
| 6 | 15000 | Battery cage, 4 floors - 3 blocks | 9.5 | 81.85 | 154 | 3,25 | 606 | 741 | 479 | 30 | 6 |
| 7 | 20000 | Battery cage, 4 floors - 4 blocks | 12.3 | 81.85 | 159 | 3,25 | 790 | 930 | 508 | 39 | 6 |

* Associated units (egg storage, nursery etc.) have included to length of poultry house.

Fig. 1: Capacities, design and building characteristics of developed poultry house models.

Three different supporting system combinations were considered for model poultry houses: steel truss- reinforced concrete column, steel truss- steel column and rigid frame system. Thus, a total of 21 different combinations were evaluated and statical calculations were carried out for each alternative.

Purlin dimensions were determined by three methods as specified in methods sections. Calculations have revealed that same sectional cross-sections could be used for all considered models since the loads acting on purlins were not large enough to create a change in cross-sections. That is why, purling dimensions were determined as I 140 for the first method, I 120 for the second method (with $\phi$ 10 connection bar) and I 120 for the side spans and I 100 for the inner spans of the third method.

Following the purling cross-section determination, SAP 90 computer software (Habibullah and Wilson, 1995) was used for statical solutions of truss systems.

When the results are evaluated for roof covering materials, insulated asbestos cement palate and insulated aluminum plate roof covers didn't create significant differences on member cross-sections, however, cross-sections become a little bit larger when the insulated asbestos cement plates were used.

In column design, initially buckling was evaluated based on column heights. Slenderness ratios for 6th and 7th model with 3.25 m side height and for the other models with 2.75 m side height were 13 and 11, respectively and there were no buckling in columns. That is why; columns were designed as stirruped unbuckling column. Considering also earthquake regulations for earthquake zones, it was found that 25x30 cm columns would be sufficient. Since the column longitudinal bars should be at least 16 mm in diameter, reinforcement bars were selected as 4 ф 16 and stirrups were selected as ф 8 / 20. Upper plank reinforcement was selected as 4 ф 10 and plank stirrups were selected as ф 8 / 20.

Based on the calculations carried out for steel truss-steel column combination, I 80 sections will be sufficient for steel columns of all models since the loads acting on columns are very close to each other.

I-sections were selected for columns and beams of steel frames. As it can be seen from the table, section dimensions increase when insulated asbestos cement plates were selected as roof cover and when the spans were increased. Also, increase in column end-moments due to span increases has forced to select larger column dimensions to bear the stress increases. I-sections with similar cross-sectional properties were selected for beams of frames with 11.00 m, 12.30 m and 14.20 m spans, regardless of the differences in spans and loadings since the beam stresses exceeds allowable stresses and allowable stresses did not allow selecting smaller cross-sections.

Foundations for model poultry houses were considered as individual column footings. Calculation based on foundation design principles and technical specifications revealed that 100x100 cm square cross-section with 5 ф 14 reinforcement in both x-x and y-y directions would be sufficient. It was envisaged that footing will be connected by 25x50 cm tie-beams with 4 ф 10 reinforcement and ф 8 / 20 stirrups.

Following the design of supporting system, effects of capacity, design system and material selection on the cost poultry house were determined. For this purpose, poultry house cost, roof cost, truss cost, roof cover cost and base area cost per hen were calculated by using the unit price tables of The Ministry of Public Works and Settlement.

Total cost per hen increases at various rates with increasing capacity and depending on planning system and construction materials. While the cost per hen was the lowest with $4.20 in 7th model (steel frame) with 20000 hen capacity, it was the highest with $10.80 in 2nd model (steel truss-reinforced concrete column) with 5000 hen capacity (Fig. 2). When the total construction cots were compared based on construction materials, it was seen that there were no significant differences among the models since the cost of form works also

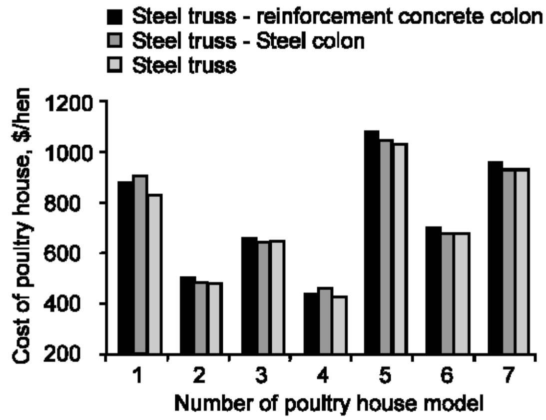



Fig. 2: Total cost of poultry house per hen

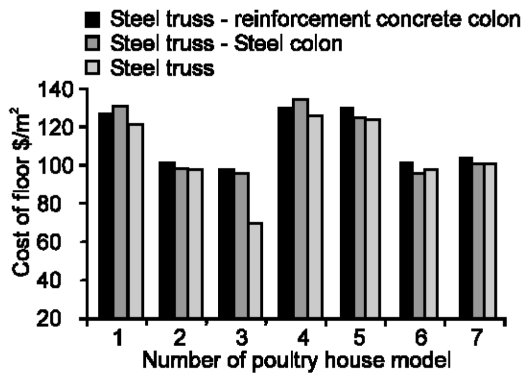



Fig. 3: Costs of floor areas

effect the cost beside the cost of concrete and steel. Another cost increasing reason in reinforced concrete members is the larger moments arisen in columns due to larger column spacing and thus requiring more reinforcement than the minimum allowable reinforcement.

As usual, roof has the highest share in construction cost. Especially in poultry houses, roof design is more critical than the other members for the control of environmental factors and for an optimization in construction costs. That is why, roof costs of each model developed in this study were separately calculated.

The ratio of roof cost in total construction cost was between 40-49%. Roof cost per hen in get-away type 5th model with 10 000 hen capacity and 14.20 m truss span was higher in steel frame system than steel truss system. Increasing spacing has increased the member forces acting on upper compression members and their cross-sections. Also, limiting the buckling ratios of compression posts and diagonals has increased the dimensions of these members and thus increased the cost.

Another factor affecting the roof cost is utilization of steel sections with different characteristics in roof construction. In truss construction, generally T sections are used for lower chords and ½ I sections are used for lower chords and also ⅃⅃ sections are preferred. That is why, effect of both alternatives on roof cost was evaluated. These values calculated for the case of insulated aluminum plates revealed that roof truss cost were higher in all models except the 2nd one with 7.80 spacing when T-sections were used for lower chords and ½ I-sections were used for upper chords.

Calculation were also carried out to determine the cost difference between insulated aluminum plate and insulated asbestos cement plate, both having the same heat conduction capacity. As it can be seen from the figure, roof costs were 1.75-2.16 times higher when the insulated aluminum plates were used instead of insulated asbestos cement plates. A 1 $m^2$ floor area costs have also been calculated and the results were given in Fig. 3. The floor area costs vary between 133.3 $ - 94.8 $.

It was also seen in this study that member sizes were not significantly affected by roof cover selection but section dimensions were a little bit larger when insulated asbestos plates were selected as roof cover. Roof truss costs for the case of insulated aluminum plates were higher in all models except the one with 5000 hen capacity and 7.80 spacing when T-sections were used for lower chords and ½ I-sections were used for upper chords. Also, when the insulated asbestos cement plates were used as roof cover in frame systems, section dimensions to be used for beams and columns have increased.

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