ECOLOGICAL FOOTPRINT IN OF DWELLING CONSTRUCTION IN MEXICO

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ABSTRACT

In present day, Mexico has a very important urban development. In a near future buildings will become more important than what they are now. There will be more demand of urban land as it becomes scarcer, and also as the environmental impacts intensify.
Currently, Mexico does not have a national certification program for sustainability of buildings of any kind. The present work evaluates impacts associated with construction using the Ecological Footprint indicator, by means of a tool developed by ARDITEC Research Group for the residential sector in Spain. It contributes to the standardization of methodology and code of home construction so it could be evaluated in different countries.
In order to analyze dwelling construction in Mexico, especially in the residential sector, a typology and project should be defined. The Ecological Footprint is based on the project bill of quantities and afterwards a breakdown of information of materials, labor and machinery is given.
The Mexican dwelling, although it has simple construction solutions, has bigger footprint per square meter because the Mexican dwelling is 50% smaller than the Spanish and elements with much energy (facilities, kitchen, bathroom, etc.) have more impact, and also the Mexican construction has biggest intensity of labor.

Keywords: Ecological Footprint, environmental impact, energy, construction, Mexico.

1.- Introduction

In Mexico data and information for the environmental impact of construction are scarce; however, according to the Commission for Environmental Cooperation [1], buildings are very responsible in consumption of energy, water, electricity while also attributed significant percentages of emissions of carbon dioxide.
The environmental sustainability has been recognized as one of the key dimensions for the development of Mexico. To achieve green growth, taking into account economic, social and environmental objectives, Mexico has made use of the policy, implementing taxes and fees based on the achievement of these objectives, environmental and social progress, in addition to the elimination of subsidies for activities that are harmful to the environment.
In the particular case of improving the environmental performance of buildings is necessary to develop indicators to qualify and quantify the weight of environmental impacts throughout their life cycle, from the extraction of raw materials to its demolition. The tools that analyze these impacts generally follow the methodology of Life Cycle Analysis (LCA) [2, 3]. Besides, other tools are emerging that analyze these impacts, such as emergy analysis [4], the material flow analysis [5], carbon footprint, ecological footprint [6], etc.
Among the studies that have chosen to use the ecological footprint indicator (EF), trying to adapt their methodology to the particularities of the building sector, we can highlight two, although both cover only the construction phase of the building. These are the Bastianoni [6] and Solis-Guzman [7].
With less impact, EF indicator has been applied to the study of the growth of high-rise districts in Tehran [8], peasant homes [9], hotels [10], and the rehabilitation of an old house [11], in addition to have developed a tool for estimating the EF and carbon footprint of buildings [12]. Finally, we have analyzed the life cycle of buildings (project realization, use and demolition) and its study as EF (energy, resources, CO2 and solid waste), applying it to an exhibition center in Wuhan (China) [13].
As mentioned, in the study of Bastianoni [6] HE two Italian buildings were calculated, taking into account mainly embodied energy of materials and the construction process (estimated as 5% of the total energy of materials) . The results are reflected in land for the absorption of CO2, forest land (for wood materials) and the area occupied by buildings. At work Solis-Guzman [7] similar calculation model developed some innovative features such as include food consumption and transfers of operators, or water consumption in the work hypothesis, which does not usually appear in studies of EF as it is not included in the general methodology of the indicator. With the inclusion of food appear footprints associated with cropland, pasture and fishing. From this research 100 housing projects were analyzed in Spain [14]. It is this latter model that applies to construction in Mexico to assess their adaptability to other constructive models.
The term EF was introduced by William Rees and Malthis Wackernagel late last century through the publication Our Ecological footprint, reducing Human Impact on the Earth [15] is a sustainability indicator to measure the impact of certain community, person, organization, city, etc. on the environment.
The indicator in its measurement takes into account the total population living or intervenes in the space, a defined time, and areas used for:

- Crops, to produce food, fiber and oils.
- Grazing to obtain meat, milk, leather, wool etc.
- Forests, to provide wood used in the production of goods or fuel.
- Sea, for seafood.
- Constructed Area, which includes homes, industries, roads and other infrastructure.

- Area of absorption, amount of forest to absorb the waste produced by burning fossil fuels like coal, oil and natural gas, used, among others, industries, machinery and transport.
- Space for conservation, reserved for the maintenance of biodiversity.

EF is the result from crosslink all these elements. For 1961, it was estimated that the global EF equivalent to 70% of the regenerative capacity of the Earth, to the eighties reached 100% and for the beginning of the new century had already exceeded the global capacity [16]. EF construction is an indicator that allows us to compare the ecological value with the various activities that comprise the sector, since the location for a building, the materials used and their origin, the building design as such, until consumption labor etc. It also allows us to analyze the life cycle of building materials comparing the same function [17].

2.- Methodology

The methodology is to be taken as a starting point in this work is the previously developed in the doctoral thesis of Solís Guzmán [7] and final dissertation work of Gonzalez Vallejo [14]. The tool lets you apply the methodology and obtain the indicator EF the building, in this case specifically the residential sector of Spain, in its construction phase. This method includes the use of resources and materials and waste generation, the aim is to develop the same tool so that it can be applied not only Spain.

The procedure for calculating the EF for the residential sector in Mexico is based on measurements of a housing project, identifying materials, labor and machinery, the following sequence is the process followed:

1. Identify the buildest dwelling type today.
2. Selecting a flagship project of the specified type.
3. Presentation of features.
4. Transfer to building technical terminology from Spain.
5. Adaptation of project to EF model.
6. Creating a resource bank of quantification from the base construction costs in Mexico and measurement project.
7. Application of indicator EF dwelling.
8. Performing an analysis of the results.
9. Compare the results with housing in Spain.

3.- Analysis of the construction sector in Mexico

According to the study results Housing Situation in Mexico [19] the largest share of investment in the country is industry, locating these projects is in developing areas outside the cities or metropolitan areas. The creation of jobs in these areas has induced increased demand for goods and services near workplaces. Hardly in the cities the authorities have been concerned about creating an urban development plan that integrates industries and their establishment requirements, resulting settlements lacking infrastructure that unfortunately occur mainly in low-income sectors, and which has been already a model of growth in cities.

The massive housing construction, the decoupling between population growth and excessive expansion of urban sprawl, have led to a wide variety of problems such as lack of equipment and adequate services, poor connectivity, enhancing the use of private cars on the use public transport and non-motorized mobility, resulting in marginalization in the city, decreased quality of life and less social cohesion.

4.- Analysis of housing in Mexico and determination of the type studied

The housing slump and irregular settlements have caused difficulties in record levels of housing construction. Taking as reference data Register of Housing (RUV) that were used for the Housing Situation Analysis in Mexico [19] is shown in the graph (fig. 1) that despite the drop in real estate and the changes it produced, the type most built detached housing is the social interest.

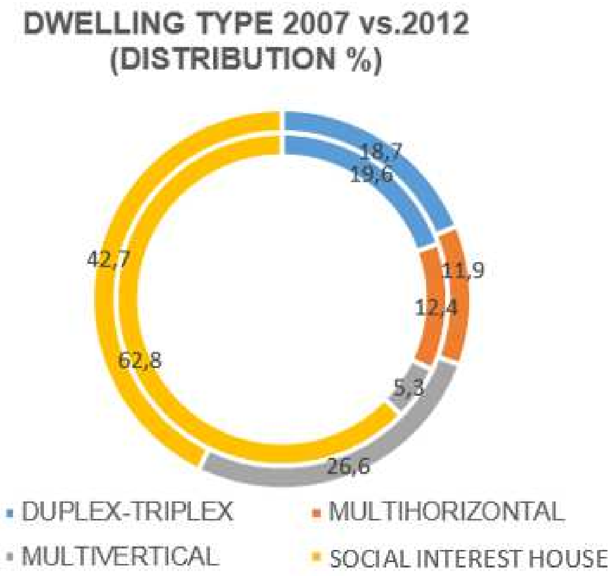


Fig. 1 “Type dwelling 2007 vs. 2012” [7]

According to the population census conducted by the National Institute of Statistics, Geography and Informatics [20] housing deficit of 8.9 million houses were calculated, and every year this number increases by 200,000. With a total of 24.3 million households in the country, Mexico needs 35% more housing to meet the current population.

To cope with this demand for housing has adopted the model of manufacturing large volumes of houses with mold carried out mainly in the most populated cities. This process consists mainly of developing a prototype model house and from it make a kind of line similar to the processes used in maquiladora production, which varies from city to city but often exceeds thousand homes. The use of this technique speeds up the time, about one month to the "gray work" or the construction process even before the details and finishes, reducing costs by making purchases materials in large quantities, and secure standardization of processes and quality control.

The project will analyze is the prototype of a complex of social housing called "Blue Mine", which is located in the suburbs of the City of Guadalupe, in the State of Zacatecas very close to an industrial area. This is a developing area that has been given on this site establishment of new foreign companies primarily in the automotive sector.

The resort was developed through a series production from a prototype or template called "Barcelona Model" which was screened thinking in the local people, being mainly of groups of workers from low-income families that make young couples with one or two children.

As for the construction characteristics of housing, the foundations are based on a concrete slab that is executed by a steel structures (columns and beams) and cover are likewise reinforced concrete. For enclosures concrete block walls coated with plaster to the tyrolean indoor and plaster and paint on the exterior, floors are covered with ceramic.

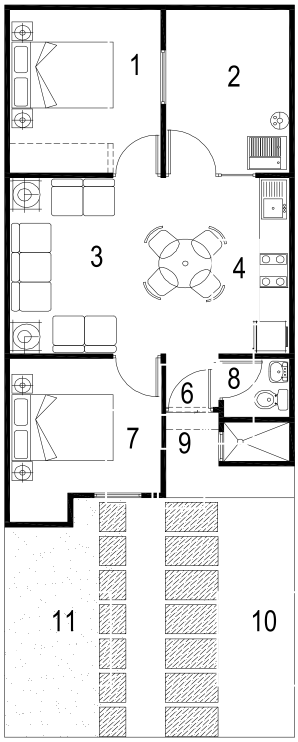


Fig. 2 “Dwelling Plant”

PROGRAMA DE NECESIDADES				
No.	**Descripción**	**Área**		
		Interior	**Exterior**	
01	Bedroom1	9,59		
02	Service yard		8,25	
03	Living room	8,58		
04	Kitchen	10,86		
06	Hall	0,94		
07	Bedroom2	8,57		
08	Bathroom	2,65		
09	Access		2.94	
10	Garage		14,45	
11	Garden		11,71	
12	Walls	3,8	0,14	
		45,00	**37,5**	**82,5**
		Surf. Total Int.	**Surface. Total Ext.**	**Surf. Total**

Tabla 1 “Program Needs”

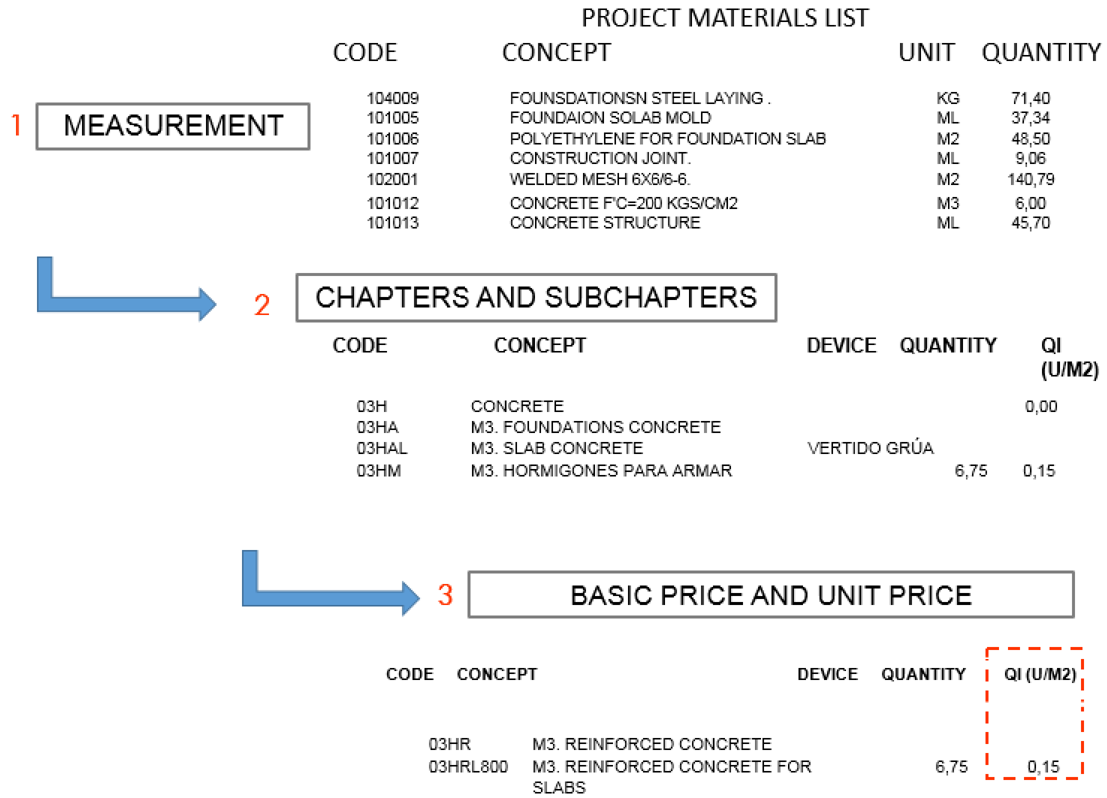
5.- Application of the model to single-family housing project in Mexico

From the data obtained from the measurement and reinforcing general information data, drawings, etc. it is necessary to adapt the project to the model.

The data obtained from the measurements are classified according to the Bank of Construction Costs of Andalusia (BCCA) [21] and expressed in units of measurement unit built (u / m2), specifying the type of resource input surface. For the case study has added new items from the original model to see the full Mexican project and not leave without estimating any part of the construction process, in this case the constructive concepts appear in the terminology of Mexico and the corresponding source code. Then gradually adapting the project to model BCCA, starting at the level of chapters and subchapters, with constructive terminology Mexico, then heading adapting the concepts included in the project to constructive terminology Spain, see Table 2.

Consequently a bank quantization project resource is created from Bank of Resource Quantification of Andalusia [21] and Cost Analysis Building Material of Mexico [22], the structure of the BCCA [21] it follows that difference direct and indirect costs resulting in a concise definition of all costs attributed to the project, besides establishing a classification of materials prices, labor and machinery, allowing apply the methodology hE indicated above. Document Mexico cost analysis [22], we obtain the components and performance of each concept.

An example of decomposed line item Bank Quantification Resources (BCRR) developed for the project, which consists of a brief description of the concept used in the technical language of Mexico is shown in Table 3.



Table

Fig. 2 “Adaptation project model”.

BCCA CODE	BCCM CODE	UNIT	DESCRIPTION				
03HRL	ECO012	M2	M2 FOUNDATION SLAB				
PROCEDENCIA							
BCCA	BCCM CODE	UNIT	CONCEPT	QUANTITY	AVERAGE	WEIGHT	Total
MATERIALES							
WW00300	AIBFE092	KG	WATER PROOFING	0,750			
CA00220	VAR025	KG	STEEL ROD	0,017			
CH03020	CPAPR015	M3	CONCRETE F´C=200KG/CM2	1,050			
WW00400	10G2H105	PZA	MESH	2,000			
CA01700	A4BAR012	KG	WIRE	0,005			
LABOR							
TO00100	1AABO	H	MASON	0,400			
TA00200	1AABY		MASON ASSISTANT	0,400			
MACHINERY							
MV00100	EQAVB001	H	CONCRETE VIBRATOR	0,200			

Tabla 3 “BCRR Example”

6.- Methodology of calculating the EF

From the data obtained from BCRR and decomposed coefficients that become footprint grasses, sea, crops, energy, forests and direct occupation, which together will give us the total footprint of the dwelling apply. For that, emission, absorption, productivity, and equivalence factors are used to transform the consumptions in partial footprints. Finally these factors make the results hectares (ha) to global hectares (gha), allowing us to compare the results with the residential sector in Spain. A brief mention the factors involved in each partial print:

- **Labor EF: food**:

A footprint of the building is added the livelihood of workers from total hours worked. While generating four types of footprint: energy, pastures, crops and productive sea. This requires obtaining the total number of hours worked by all employees which are obtained from the analysis of decomposed BCCR. For the study case a total of 1470 hours of work was obtained for the dwelling construction. It is also necessary to determine what percentage of the worker performs spending on food. One hypothesis was based on the number of hours worked, and data regarding food were obtained from the study "Feeding the Mexicans. Social and economic changes and their impact on dietary habits "[23], of which the percentage of food distribution was obtained in the diet of an average Mexican, being the most important meat consumption and subsequently the grain.

- **Labor EF: mobility**:

It is determined from the definition of the type of transport, the average distance traveled by vehicles, and fuel consumed.

- It was established as a kind of private vehicle transport. In the case of construction in Mexico as usual is that the site manager and supervisor collect workers who do not have own vehicle at a certain point and then take them to work. So we start with this hypothesis.
- Was established average distance traveled from 15-30 km by vehicle operators on the go.
- The average vehicle occupancy is 8 people. For the number of workers, we know the total number of hours worked and the effective length of the work day, both data will be obtained from BCRR.
- For the fuel calculation are going to employ consumption coefficients car in Mexico, which in the case of gasoline is 9.57 l/ km [24].

- **Labor EF: Urban Solid Waste**:

USW project are obtained from the data of the Report on the Status of Environment in Mexico. Compendium of Environmental Statistics. Key Indicators and Environmental Performance [13] according to which if the annual generation of municipal solid waste per capita in Mexico is calculated, an average of 360 kg is obtained. Which according to the National Institute of Ecology [12] of the total percentage of waste, 53% are organic, 28% are potentially recyclable, the rest belongs to other waste. Also considered to perform the calculations the energy intensity of the materials [14]. The results of urban solid waste EF shown in conjunction with construction waste and demolition.

- Building Materials EF:

A energy footprint is going to be add to the materials, the values of this energy is taken from the extraction, manufacturing, transportation and application thereof. Using pass coefficients the amounts of materials in their various units (m, m2, kg., Etc.) will be converted by weight (kg). For the study case the most impact materials are steel, concrete and polyethylene respectively.

- **Machines EF**:

The machinery EF is determined from the volume of fuel consumed. Calculating hours machinery used is made by measuring project BCRR data and to determine from this the economic cost of using this machinery. It is considered the hypothesis of work [7,14] where 20% of the hourly cost of machinery is considered as fuel cost

[24] which includes maintenance but depreciation. The liters of fuel are determined from the actual cost of Mexico, 0.72 € / l [24].

- **Electricity EF**:

In the absence of accurate data on the billing of electricity in building work in Mexico the hypothesis from Antonio Freire's work in Spain [26] is followed. The total power consumption of the execution of the work is split between fuel and electricity, and is considered that the origin of electricity in Mexico is by combustion of hydrocarbons.

- **Construction Waste EF**:

There are two types of waste: excavation land and mixed waste which remains materials generated in the execution of the work and packages containing materials.
EF waste will be determined from Wackernagel methodology [27], according to which the trace associated with the deposition of waste or effluent is calculated similarly that materials with the same energy intensity only subtracting the percentage of energy that can be recovered for recycling. In the procedure using all consumisions are associated with to energy footprint.

- **Water consumption EF**

Water consumption will be counted even if they are not covered by EF method. It will determine the range of water consumption in residential construction works, following the Trigo Ledesma`s work [28].

- **Built area EF:**

The EF of the built surface is obtained directly from the transformation undergone by the soil analyzed. Such impact is obtained by calculating the area consumed by the house. As defined EF methodology, we will consider is the surface area used directly productive.

7.- Results

Partial results are obtained for each type of footprint and from these is that it determines the Total EF. Table 4 shows the overall results. The EF dwelling is 25.109 global hectares, which corresponds to 0,403 global hectares per square meter of construction. EF shows that the greatest impact is on energy and within the relevant materials. EF pasture from food also has an important place while the EF direct surface is almost negligible.
In Figure 3 the results of EF the Mexican project are shown and those obtained after calculating the residential sector EF Spain [14] dwelling of similar characteristics in both countries. The home has similar characteristics the research is the detached single level and whose HE typology is 0.362 gha / m2. The house of Mexico presents a greater HE, 0.403 gha / m2, mainly because it is 50% smaller than the Spanish so much incorporated elements facilities, bathrooms, kitchen, etc. energy, have greater impact by built square meter. The Mexican dwelling also has more manpower so the footprint of food is also higher.

TOTAL ECOLOGICAL FOOTPRINT						
	EF Type (hag)					
Impact	Energy	Forest	Grass	Sea	Crops	Consumed Surface
Machinery	0,004					
Electricity	0,180					
Water		0,015				
Food	1,277		4,915	0,410	2,209	
Movility	0,001					
Urban Solid Waste	0,210					
Materials	15,725					
Construction Waste	0,148					
Direct occupation						0,016
Partial EF (hag)	17,544	0,015	4,915	0,410	2,209	0,016
Total EF (hag)	**25,109**					
Total EF (hag/m2)	**0,403**					

Table 4 “Total EF”.

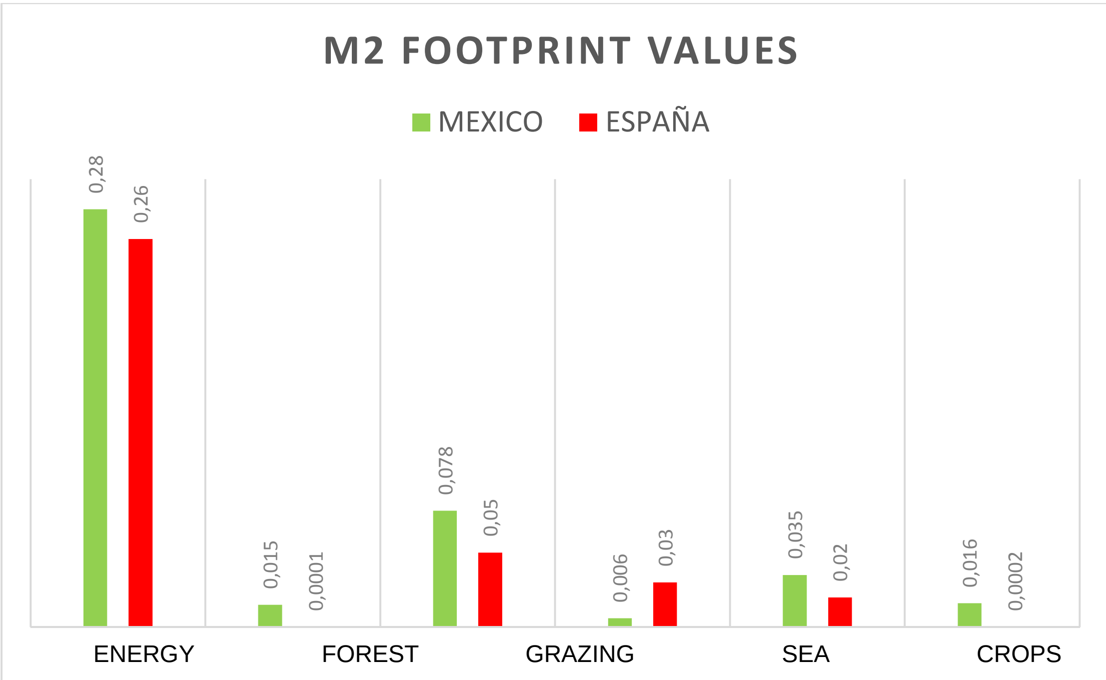


Figura 3 “Comparative graphic dwelling EF Mexico – Spain”.

In Figure 3 the EF results of the project are shown and those obtained after calculating the Residential Sector EF in Spain [14] for a comparison of the EF dwelling of similar characteristics in both countries. In this case the home that has similar characteristics the research is the type of one level and whose EF is 0.362

hag / m2. The house has a greater EF in Mexico, mainly because it is 50% smaller than the Spanish so much incorporated elements facilities, bathrooms, kitchen, etc. energy, have the greatest impact per square meter built.

8.- Conclusions

After some modifications to the considerations of ecological footprint model for Spain has been able to obtain the EF for the representative Mexico project. The road to reach the result has not been easy, since as mentioned throughout the application process, much of the data are obtained from the measurement and project budget, appearing in Spain and Mexico various technical terms of construction for the same concept and sometimes even different units of measurement.

The mexican dwelling, despite having simple constructive solutions have larger footprint per square meter due to the Spanish average household size that is 50% smaller and some elements (facilities, kitchen, bathroom, etc.) have greater impact.

Once EF indicator for representative apartment in the residential area of Mexico was obtained it can be concluded that the model can be generalized application and not just in Spain.

Future developments should be flexible BCRR for possible application in any region, which provides for a wider range of options for items and which in turn permits include special items

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