© Strojniški vestnik 46(2000)6,347-358
ISSN 0039-2480
UDK 551.506:536.2:697.9(569.1)
Izvirni znanstveni članek (1.01)
© Journal of Mechanical Engineering 46(2000)6,347-358
ISSN 0039-2480
UDC 551.506:536.2:697.9(569.1)
Original scientific paper (1.01)

Sistemizacija, organizacija, razvoj in uporaba podatkovne baze urnih postavk meteorološkega leta za območje Damaska

Sistematization, Organization, Development and Utilization of an Hourly Reference Meteorological Year Database for Damascus Zone

Kamal Skeiker

Vremenske podatke za območje Damaska je od leta 1970 do 1993 spremljala meteorološka postaja, ki jih je nato pregledala in uredila. Z uporabo teh podatkov je bila organizirana in razvita podatkovna baza za referenčno meteorološko leto "RMY", glede na naslednje modele: 1-urno mesečno povprečje, 2-urno povprečje, 3-dnevno količino sonca, merjeno v urah.

Računalniški program LOS-A0 za dinamične analize prenosa toplote v stavbah je bil prilagojen za uporabo glede na delovne razmere in letne čase v Siriji in je bil pripravljen na podlagi urnega mesečnega povprečja. Z novo verzijo CLIMA, ki je bila zasnovana na podlagi urnega povprečja, so lahko dobili optimalno obdobje skozi vse leto. Po natančnih primerjavah in analizah dobljenih rezultatov obeh omenjenih različic, so se odločili za CLIMA program.

(Ključne besede: podatki meteorološki, baze podatkov, programi računalniški, analize dinamične)

The weather data for the Damascus zone for the years 1970 through 1993 as measured by the Department of Meteorology were obtained, examined and reconditioned. Using these measured data, a Reference Meteorological Year "RMY" Database was organized and developed according to the following patterns: 1- monthly average of hourly weather data,2- hourly weather data,3- daily sunshine hours.

The LOS-A0 computer program for the dynamic analysis of heat transfer in buildings was modified for use according to the working conditions and weather seasons in Syria. It was provided with an hourly weather database of the first pattern. This last version was developed, and a new version CLIMA, in which the calculation is carried out for an optional period during the year, was obtained. The computer program CLIMA was provided with an hourly database of the second pattern. These two versions were used to study an enclosure as an example. After detailed analysis of the calculated results obtained by each of the two mentioned versions, the computer program CLIMA was chosen.

(Keywords: meteorologic data, data bases, computer programs, dynamic analysis)

0 UVOD

Zaradi naslednjih dejavnikov, je bila zadnji dve desetletji povečana pozornost racionalizaciji porabe energije in iskanju novih energijskih virov:
- povečane letne porabe energije, ki izhaja iz naraščanja števila prebivalstva in ekonomskega razvoja;
- okoljevarstvenih učinkov, ki izhajajo iz porabe energije.

Zaradi tega je racionalizacija porabe energije in uporaba novih energijskih virov postala nuja. V mnogih državah so vlade zaprosile znanstvenike in raziskovalce za izvedbo raziskav in projektov, da bi razrešili potencialni problem

0 INTRODUCTION

During the last two decades, increased attention has been paid to the rationalization of energy consumption and the search for new energy resources, as a consequence of the following factors:
- The increased rate of energy consumption per annum, as a result of an increasing population and economic growth.
- Environmental effects arising from the use of energy.

As a result, the rationalization of energy consumption and the use of new energy resources has become an urgent matter. Governments in many countries have been motivated to request academics and researchers to carry out research and experimental tako imenovane energijske krize. Ti so natančno proučili racionalizacijo energijske porabe in zmanjšanje stroškov za energijo v različnih področjih.

Raziskave poslopij so se nanašale na: razvoj matematičnih modelov za izračun in simuliranje toplotnih sistemov, organizacijo in avtomatizacijo notranjih hladilnih sistemov, oblikovanje pasivnih in aktivnih toplotnih solarnih sistemov, uporabo izolacije na zunanjih površinah in dvojno zasteklitev oken.

Poraba energije različnih panog v Siriji: 42% za zgradbe in kmetijstvo, 41% za transport in 17% za industrijo. Glede na to, da se največji del energije porabi v poslopjih so raziskave usmerjene predvsem v to smer.

V okviru razvoja matematičnih modelov za izračun in simuliranje sistemov, smo poskušali izpeljati naslednje:

- Razviti podatkovno bazo "RMY", da bi jo uporabili skupaj s sedanjimi računalniškimi programi za dinamične analize prenosa toplote v poslopjih "model LOS-A0". Razvoj takšne podatkovne baze je temeljil na razpoložljivih urnih podatkih o vremenu za območje Damaska, ki jih je merila meteorološka postaja oddelka za meteorologijo. To podatkovno bazo štejejo za prvo takšne vrste na tem področju, katera vključuje urne vrednosti za naslednje vremenske parametre:
  1- temperaturo suhega zraka,
  2- temperaturo vlažnega zraka,
  3- temperaturo rosišča,
  4- relativno vlago,
  5- atmosferski tlak,
  6- hitrost vetra in smer,
  7- celotno stopnjo sončnosti in tip oblačnosti,
  8- intenzivnost globalnega sončnega sevanja.

  Upoštevana je tudi dnevna količina sonca merjena v urah.
- Prilagoditi računalniški program LOS-A0 okoliščinam in letnim časom v Siriji.
- Reorganizirati računalniški program LOS-A0 in ga prilagoditi za računanje obdobja v letu izbranega po prosti presoji.

1 PRIDOBITEV, NADZOR IN OBDELAVA VREMENSKIH PODATKOV ZA OBMOČJE DAMASKA

Da bi organizirali in razvili podatkovno bazo RMY, so potrebni urni podatki, ki so omenjeni v uvodu. Podatki so bili dobljeni na mednarodnem letališču v Damasku in v Kharabu. Mednarodno letališče Damask se nahaja na 32°36´ vzhodne zemljepisne dolžine, 26°33´ severne zemljepisne širine in leži 608 m visoko nad morjem. Postaja v Kharabu je locirana na 36°32´ vzhodne zemljepisne dolžine,

projects with the aim of overcoming the potential problems of the so-called energy crisis. Academics and researchers looked closely at energy consumption rationalization and decreasing its costs in various fields.

Buildings research was directed towards: the development of mathematical models for thermal system calculations and simulations, organization and automation of internal air-conditioning systems, design of passive and active solar thermal systems, use of outer surfaces thermal insulation and double-glazed windows.

The energy consumption of various sectors in Syria is: 42% for building and agriculture, 41% for transportation and 17% for industry [1]. Since the greatest share of total energy consumption is in buildings, it is useful to carry out research in this field.

Within the framework of the Development of Mathematical Models for Calculation and Simulation of Engineering Systems, we therefore attempted to carry out the following:

- To develop a RMY Database, to be used with existing computer programs for dynamic analysis of heat transfer in the building "model LOS-A0" [2]. Development of such an RMY Database was based on the available hourly weather data for the Damascus zone, which were measured by the Department of Meteorology. This Database is considered as the first of its kind in this field that includes hourly values for the following weather parameters in the Damascus zone:
  1- air dry-bulb temperature,
  2- air wet-bulb temperature,
  3- air dew-point temperature,
  4- relative humidity,
  5- atmospheric pressure,
  6- wind velocity and direction,
  7- global cloudless degree and cloud type,
  8- global solar radiation intensity.

  Daily sunshine-hours values are included too.
- To modify the LOS-A0 computer program according to the working conditions and weather seasons in Syria.
- To re-organize the LOS-A0 computer program and adapt it to calculate for an optionally determined period in a year.

1 OBTAINMENT, SCRUTINY AND RECONDITION OF DAMASCUS ZONE WEATHER DATA

In order to organize and develop the RMY Database, the hourly weather data mentioned in the introduction are required. The Department of Meteorology agreed to provide the available data. They supplied us with hourly weather data from the meteorological stations in Damascus International Airport and in Kharabo. Damascus International Airport Station is located at 32° 36' east longitude, 26° 33' north latitude and at an elevation of 608 m above the sea level. Kharabo

30°33′ severne zemljepisne širine, nadmorska višina je 620 m.

Podatki od leta 1970 do 1993 so nam na voljo za parametre 1 do 7. Za osmi parameter so na voljo le od leta 1971 do 1974 in od 1984 do 1986. Imamo podatke tudi za dnevno količino sonca, merjeno v urah od leta 1978 do 1988. V primeru manjkajočih parametrov so bile kode 99, 999, 99.9, 999.9 in 9999.9, ki so nakazale pomemben stolpec.

Podatki so bili razdeljeni v podmape, ki so morale vsebovati toliko vrstic, kolikor je bilo merjenih ur oziroma dni v obdobju (to je 8760 oz. 365). Računalniški program ERRLINE.F OR je bil pripravljen za določitev ur ali dni v letu, ko ustreznih podatkov ni bilo na voljo.

Da bi dopolnili podatke, so bili manjkajoči in netipični podatki zamenjani z ocenjenimi vrednostmi. Te vrednosti so bile izračunane po postopku interpolacije in so temeljile na ustrezni vrednosti parametra na dan, ko je podatek manjkal.

2 ORGANIZIRANJE IN RAZVOJ PODATKOVNE BAZE RMY

Na tej stopnji se pri analizi podatkov pojavi vprašanje: "Kateri model naj bi uporabili za predstavitev niza podatkov?" Čeprav je na to vprašanje težko odgovoriti, poznamo nekaj tehnik, ki nam pri sprejemanju odločitve pomagajo z analiziranjem.

Po praktičnih izkušnjah je bilo ugotovljeno, da je uporaba normalne porazdelitve najprimernejša za označevanje mnogih fizikalnih meritev in ostalih vrst podatkov. Izbran je bil za predstavitev opazovanih podatkov za vsako uro v letu (ali za vsako sončno uro). Normalna porazdelitev, označena kot $N(\mu, \sigma^2)$, je opisana z gostoto verjetnosti:

station is located at 36° 32' east longitude, 30° 33' north latitude and at an elevation of 620 m above the sea level.

The data for the years 1970 through 1993 for each of the parameters 1 to 7 were provided. The data for the 8th parameter, were provided for the years 1971 through 1974 and for 1984 through 1986. Daily sunshine-hours data for the years 1978 through 1988 were also provided. For the case of a missing parameter the codes 99, 999, 99.9, 999.9 or 9999.9 were indicated in the relevant column.

The data were divided into sub-files, each of which included data values of the measured parameters for one year only. These sub-files had to contain a number of lines equal to the number of measuring hours or days per annum, (that is 8760 or 365). A computer program, ERRLINE.FOR, was prepared to determine the hours or days in a year, where the relevant data were not recorded. It also determines the lines with which the codes indicating missing data, for all the parameters included in the file, are recorded.

To complete the data, missing and atypical data were replaced by estimated values. These values were generated by an interpolation method, based on the corresponding parameter values for the day on which the missing data occurred.

2 ORGANIZING AND DEVELOPING AN RMY DATABASE

At this stage an important question, which normaly arises during the analysis of data; namely, "which model should be used to describe a given set of data"?, was raised. Although this is generally a difficult question to answer, there are several techniques available which can assist the analyst in making such a decision.

The normal distribution model is found from practical experience to be appropriate for many types of physical measurements and other types of data.. It was shosen for representing the observed data for each hour of the year (or each day for sunshine hour). The normal distribution, denoted by $N(\mu, \sigma^2)$ is described by the probability density function:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right], \qquad -\infty < x < \infty \tag{1}$$

μ pomeni porazdelitev, σ pa pomeni standardno odstopanje porazdelitve ([3] do [5]). Krivulja je simetrična na μ in ima obliko zvonca. Normalna porazdelitev prikazuje standardno odstopanje (σ), ki omogoča najboljši pregled razpršitve, tako kakor *m* omogoča najboljši pregled glavne tendence. Medtem ko je porazdelitev simetrična na μ, so povprečna vrednost, srednja vrednost in najpogostejša vrednost vse enake μ ([6] in [7]).

Za model preverjanja domnevne porazdelitve je bila uporabljena Kolmogorovova metoda ([3] in [8]). Postopek te metode je zelo preprost. Primerjati je treba kumulativno frekvenco podatkov s kumulativno frekvenco krivulje

Where, μ is the mean of the distribution and σ is the standard deviation of the distribution ([3] to [5]). It has the well-known bell shape and the curve is symmetrical about μ. The normal distribution demonstrates the standard deviation (σ) may be looked upon as the best measure of dispersion, just as the mean (μ) may be seen as the best measure of central tendency. Since the distribution is symmetrical about μ, the mean, median and mode coincide, all being equal to μ ([6] and [7]).

We may be unsure as to whether a particular probability distribution is appropriate for our observations. The Kolmogorov method ([3] and [8]) was used to check whether an assumed distribution model is adequate to represent a set of data. The principle of the Kolmogorov approach is very simple. It involves teoretične porazdelitve. Ko so hipotetične in eksperimentalne krivulje narisane, lahko preberemo največjo navpično razliko med njima in lahko primerjamo te vrednosti s tabeliranimi vrednostmi. Ta metoda uporablja vsak posamezni podatek in je tako enako učinkovita za manjšo in večjo količino podatkov.

V primeru normalne porazdelitve lahko izračunamo funkcijo teoretične kumulativne porazdelitve:

comparing the cumulative frequency of the data to be tested with the cumulative frequency curve of the hypothesized (theoretical) distribution. When the hypothetical and experimental curves have been drawn, the test statistics are obtained by finding the maximum vertical difference between them, and comparing this value with a set of tabulated values. This method uses each individual data point and so is equally effective for either small or large sets of data.

In the case of the normal distribution, the theoretical cumulative distribution function is given by:

$$F(z) = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{z^2}{2}\right) dz \qquad (2)$$

To enačbo zasledimo v mnogih zbirkah statističnih preglednic za različne vrednosti z. Najprej moramo spremeniti začetne podatke v standardno spremenljivko z. To storimo z naslednjo enačbo:

which is well-tabulated and given in many collections of statistical tables for different values of z. So we must first transform the original data, which might have any values for their mean and standard deviation, into the standard normal variable, z. This is done using the equation:

$$z = (x - \mu) / \sigma \qquad (3)$$

Predpostavljamo, da si določeni podatki sledijo $x_1 \leq x_2 \leq x_3 \ldots\ldots \leq x_n$. Krivulja kumulativne frekvence množice je določena z:

Suppose that we observe an ordered set of data $x_1 \leq x_2 \leq x_3 \ldots\ldots\ldots\ldots \leq x_n$. The set cumulative frequency curve is defined by:

$$S_n(x_j) = j/n\,;\; j = 1,2,3\ldots..n \qquad (4)$$

$$S_n(x) = 0 \text{ za / for } x < x_1 \text{ in / and } S_n(x) = 1 \text{ za / for } x \geq x_n \qquad (5)$$

Preveritveni postopek je določen z naslednjimi koraki:
Korak 1.
H_0: x ima obliko krivulje kumulativne frekvence $F(z)$.
H_1: x nima oblike krivulje kumulativne frekvence $F(z)$.
Korak 2. Izberemo γ, stopnjo signifikantnosti preveritve.
Korak 3. Določitev odklonitvenega področja $R = \{D_{max} \mid D_{max} > D_n^{(\gamma)}\}$, kjer $D_n^{(\gamma)}$ dobimo iz ustrezne preglednice.
Korak 4. Izračunamo statistiko: $D_{max} = \max_i \{| F(z_i) - S_n(x_i) |, | F(z_i) - S_n(x_{i-1}) |\}$.
Korak 5. Če je $D_{max} > D_n^{(\gamma)}$, H_0 ni primeren, nakar sledi, da $F(z)$ ne popiše podatkov; drugače pa ob sprejemu H_0 izhaja, da $F(z)$ popiše podatke.

Z uporabo Kolmogorovove metode za testiranje pravilnosti porazdelitve je bilo ugotovljeno, da so razpoložljivi meteorološki podatki za vsako uro v letu (ali število ur sonca na dan) prikazani kot normalna porazdelitev. Značilno vrednost za vsak parameter so dobili s povprečnimi vrednostmi za vsako uro (ali za vsak dan v primeru sončnih ur). Njen razpon je določen s pogojem:

The test procedure is now defined as follows:
Step 1.
H_0: x has cumulative frequency curve $F(z)$.
H_1: x does not have cumulative frequency curve $F(z)$.
Step 2. Select γ, the level of significance of the test.
Step 3. Specify the rejection region $R = \{D_{max} \mid D_{max} > D_n^{(\gamma)}\}$, where $D_n^{(\gamma)}$ is obtained from the relevant table.
Step 4. Calculate the statistic: $D_{max} = \max_i \{| F(z_i) - S_n(x_i) |, | F(z_i) - S_n(x_{i-1}) |\}$.
Step 5. If $D_{max} > D_n^{(\gamma)}$, reject H_0 and conclude that $F(z)$ does not describe the data; otherwise, accept H_0 and conclude that $F(z)$ describes the data.

Testing for normality of distribution, using the Kolmogorov method, it was found that the available sets of meteorological data for each hour of the year (or each day for sunshine hours) are drawn from a normal distribution. Thus for each parameter, the mean value of the overall available years was taken for each hour (or each day in the case of sunshine hours) of the year and defined as a representative value. Its range is defined by the condition:

$$\bar{x} - 1{,}96(\sigma/\sqrt{n}) < \mu < \bar{x} + 1{,}96(\sigma/\sqrt{n}) \qquad (6)$$

Izraz (6) podaja 95% zanesljivost povprečnega intervala v primerjavi z mejo zaupanja 1,96 $(\sigma/\sqrt{n})$.

Expression (6) gives the 95% confidence interval of the mean with the confidence limit 1,96 $(\sigma/\sqrt{n})$.

2.1 Ureditev podatkovne zbirke RMY

Cilj vnaprej pripravljenih vremenskih podatkov je bil določitev urnih stopenj za vsak vnaprej določen fizični parameter. V ta namen je računalniški program (MEANVAL.FOR) izračunal in dobil rezultate (REFERENC.YER) z 8769 vrsticami in 578160 bajti. Urni vremenski podatki za RMY so bili vneseni kakor prikazuje naslednji primer:

2.1 Organization of the RMY Database

On the basis of the previously prepared weather data, the aim was to quantify the hourly rates for each of the predetermined physical parameters. For this purpose, a computer program (MEANVAL.FOR) was prepared for the calculations and recording the results in a separate file (REFERENC.YER) with 8760 lines, and a size of 578160 bytes. The hourly weather data for a RMY were recorded in free format according to the arrangement shown in the following example:

DAN DAY	URA HOUR	DBT	WBT	DPT	RH	SP	WS	WD	TC	CTYP	MGO
-	-	°C	°C	°C	%	mbar	m/s	°	0-8	0-9	W/m^2
1	1	3	2,2	1	87	948,2	3	16	3	0	0
1	2	3	2,2	1	87	948,2	3	15	3	0	0
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
1	9	4,5	3,4	2	84	949,3	2	13	5	0	290

Z uporabo računalniškega programa MEANVAL.FOR je bilo mogoče tudi določiti dnevno stopnjo sonca. Ta nova različica se je imenovala MEANSUN.FOR, rezultati so bili zapisani v REFERENC.SUN s 365 vrsticami in velikosti 6205 bajtov. Naslednji primer prikazuje vnos podatkov za količino sonca na dan v urah.

The MEANVAL.FOR computer program was also modified to quantify the daily sunshine hour rate. This new version was named MEANSUN.FOR the results were recorded in the file REFERENC.SUN with 365 lines and a size of 6205 bytes. The daily sunshine hours for a RMY were recorded in free format according to the arrangement shown in the following example.

MESEC MONTH	DAN DAY	URA HOUR
1	1	4,4
1	2	5,2
1	3	3,8
1	4	4,8

2.2 Razvoj podatkovne baze RMY glede na zahteve prilagojene strukture ter prilagojenega in reorganiziranega računalniškega programa LOS-A0

Sedanji računalniški program LOS-A0 z nizom podatkov RMY določi mesečno povprečje za vsak vnaprej določen fizični parameter. Namen je bil razviti program za numerično simuliranje toplotnega sistema za izbrani časovni interval v letu.

Računalniški program REFERLOS.FOR je bil pripravljen za naslednje namene:

- Za branje vrednosti podatkovnega niza RMY iz dokumenta REFERENC.YER.
- Za določitev mesečnega povprečja z uporabo urnih vremenskih podatkov za vsak parameter iz dokumenta REFERENC.YER.
- Za zapisovanje povprečne mesečne vrednosti urnih vremenskih podatkov v ločen dokument.
- Za kopiranje vsebine dokumenta REFERENC.YER v drug dokument

2.2 Development of the RMY Data Base According to the Requirements of the Construction of Modified and Modified & Re-Organized LOS-AO Computer Programs

The existing LOS-A0 computer program requires an RMY Database, in which the monthly average of hourly weather data for each of the predetermined physical parameters are recorded in a specific sequence. The aim was to develop this program for use in numerical simulation of thermal systems for an optionally determined time interval within the year.

For this purpose, the computer program REFERLOS.FOR was prepared to serve as a means for executing the following:

- To read the values of the RMY Database from the file REFERENC.YER.
- To quantify the monthly average of hourly weather data for each of the included parameters in the file REFERENC.YER.
- To record the quantified monthly average of hourly weather data in a separate file.
- To re-record the contents of the file REFERENC.YER in a separate file.

3 PRILAGODITEV IN RAZVOJ RAČUNALNIŠKEGA PROGRAMA LOS-A0

Cilj je bil preskrbeti oz. ″opremiti″ sirsko Tehnično knjižnico z ustreznim matematičnim modelom in računalniškim programom za digitalno simuliranje termičnega sistema poslopij in drugih inženirskih sistemov vključenih v to omrežje.

Računalniški program LOS-A0 je bil prilagojen za različne delovne razmere (počitnice, čas začetka/prekinitve ogrevanja oz. hlajenja) in letne čase v Siriji.

Sedaj se lahko bolje osredotočimo na delovanje in metodo izračuna LOS-A0, ki je sistematično orodje za študiranje, načrtovanje in računanje različnih poslopij (toplotni sistemi).

Dinamična analiza prenosa toplote v stavbah je "vodena" z matematičnim modelom, ki upošteva enourni prirastek. Metodo toplotnega ravnotežja prostora uporabljamo za začetek kalkulacije neustaljenega prenosa toplote v zgradbah. Z uporabo te metode dobimo linearni sistem m+1 enačb za m poljubnih površin in temperatur zraka. Pri zunanjih površinah je prevajanje toplote skozi steno popisano z konvekcijo in sevanjem. Energijska bilanca za površino i ob času t:

3 MODIFICATION AND DEVELOPMENT OF THE LOS-A0 COMPUTER PROGRAM

The aim was to provide the Syrian Technical Library for Heat Transfer Sciences with the relevant mathematical model and computer program for digital simulation of the thermal system of a building, and other engineering systems included in this framework.

The LOS-A0 computer program was modified to make it adaptable for use according to the working conditions (holidays, and time of starting/stopping of heating/or refrigeration) and weather seasons (months of winter and summer) in Syria.

Since the LOS-A0 computer program is a scientific tool for studying, planning and calculating various buildings (thermal systems), where unusual planning or operating conditions are requested to be taken into account, it is useful to focus on the principle used and the method of calculation.

In the LOS-A0 computer program, the dynamic analysis of heat transfer in buildings is conducted according to the adopted mathematical model by using a one-hour time increment. As a starting point for the calculation of non-stationary heat transfer in a building, the "Room Thermal Balance Method" was adopted. Using this method we obtain a linear system of m+1 equations for m unknown surfaces and air temperatures. At each boundary surface of the enclosure, the heat conducted through the surface is removed from it by a combination of convection and radiation. The energy balance for the surface i at time t would give:

$$q_{i,t} = \alpha_{ii}(\vartheta_{ia,t} - \vartheta_{ii,t}) + \sum_{k=1,k\neq i}^{m} g_{i,k}(\vartheta_{ik,t} - \vartheta_{ii,t}) + R_{si,t} \qquad (7)$$

Leva stran te enačbe pomeni prevodni toplotni tok. Desna stran (od leve proti desni) pomeni konvekcijo, sevanje ter notranje toplotne vire (sončno sevanje skozi okna, luči, oprema, stanovalci).

Prevod toplote skozi homogeno konstrukcijo (stena, strop, tla) določimo s toplotnimi odzivnimi faktorji (TRFs), ki so določljivi po Kusudovi oz. Stephensonovi metodi [9] in [10]. "Obnašanje" časovne temperaturne odvisnosti na zunanji in notranji strani je ponazorjeno kot:

- trikotna impulzna funkcija (Kusudov ali Stephensonov tip TRFs)
- skupina harmonskih (Stephensonov tip TRFs)

Prevod toplote skozi homogeno konstrukcijo i ob času t je izražen kot:

The left side of this equation represents conducted heat flow rate. The right side (from left to right) represents convected, radiated and radiated from internal heat sources (solar energy coming through the windows, lights, equipment and occupants) heat flow rates, respectively.

The conducted heat flow rate $q_{i,t}$ through a system of homogeneous slabs i (composite wall, roof and floor) is defined by using the so-called thermal response factors (TRFs) method. TRFs are calculated by making use of either the Kusuda or Stephenson method [9] and [10]. Time-dependent temperature behavior on the outer and inner side, of the system, respectively, is specified as:

- Triangle unit-pulse functions (Kusuda-type and Stephenson type TRFs),
- Group of harmonics (Stephenson type-TRFs).

The conducted heat flow rate through a system of homogeneous slabs i at time t may be expressed in the form:

$$q_{i,t} = \sum_{j=0}^{n} X_{i,j}\vartheta_{ii,t-j} - \sum_{j=0}^{n} Y_{i,j}\vartheta_{oi,t-j} + SR_i q_{i,t-1} \qquad (8).$$

Enačbo (8) vstavimo v enačbo (7) in po ureditvi dobimo:

Substitution of equation (8) into equation (7) and convenient reorganization yields:

$$(X_{i,0} + \alpha_{ii} + \sum_{k=1,k\neq i}^{n} g_{i,k})\vartheta_{ii,t} - \sum_{k=1,k\neq i}^{n} g_{i,k}\vartheta_{ik,t} - \alpha_{ii}\vartheta_{ia,t} = -\sum_{j=1}^{n} X_{i,j}\vartheta_{ii,t-j} + \sum_{j=0}^{n} Y_{i,j}\vartheta_{0i,t-j} - SR_i q_{i,t-1} + R_{si,t} \qquad (9).$$

Sistemu m enačb (9) dodamo sledečo enačbo energijske bilance za notranji zrak:

To the system of m equations (9) the following equation of energy balance for enclosure air is added:

$$\sum_{i=1}^{m} A_i\ \alpha_{ii}\ (\vartheta_{ii,t} - \vartheta_{ia,t}) - (q_{mf,t} + q_{mv,t})c_p\,\vartheta_{ia,t} = -q_{mf,t}\ c_p\,\vartheta_{oa,t} - q_{mv,t}\ c_p\ \ \vartheta_{v,t} - R_{ci,t} \qquad (10).$$

V zgornjih dveh enačbah (9) in (10) nimamo znane temperature površine $\vartheta_{ii,t}$, niti temperature zraka $\vartheta_{ia,t}$ ob času *t*. Tak sistem je podan v obliki matrike:

Equations (9) and (10) form a linear system of m+1 equations with m unknown surface temperatures $\vartheta_{ii,t}$ and air temperature $\vartheta_{ia,t}$ at time *t*. Such system can be expressed in the following matrix terms:

$$\begin{bmatrix} a_{1,1} & a_{1,2} & - & - & - & a_{1,m+1} \\ a_{2,1} & a_{2,2} & - & - & - & a_{2,m+1} \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ a_{m+1,1} & a_{m+1,2} & - & - & - & a_{m+1,m+1} \end{bmatrix} \begin{bmatrix} \vartheta_{1,t} \\ \vartheta_{2,t} \\ - \\ - \\ \vartheta_{m,t} \\ \vartheta_{a,t} \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ - \\ - \\ - \\ b_{m+1} \end{bmatrix} \qquad (11)$$

iz katere lahko določimo neznane temperature površin in zraka [ϑ_t]. Ko je vektor temperature [ϑ_t] določen, je lahko toplotna obremenitev ϕ_t prostora izračunana z uporabo energijske ravnovesne enačbe (10) za notranji zrak:

from which the unknown surface and air temperatures [ϑ_t] can be defined. Since the vector of temperaturesis [ϑ_t] determined, the thermal load ϕ_t of the enclosure can be calculated by using the energy balance equation (10) for enclosure air:

$$\phi_t = \sum_{i=1}^{m} A_i\ \alpha_{ii}\ (\vartheta_{ii,t} - \vartheta_{ia,t}) + q_{mf,t}\ c_p(\vartheta_{oa,t} - \vartheta_{ia,t}) + q_{mv,t}\ c_p\ (\vartheta_{v,t} - \vartheta_{ia,t}) + R_{ci,t} \qquad (12)$$

V enačbi (12) pomeni negativna vrednost ϕ_t ogrevalne obremenitve, pozitivna vrednost pa hladilne obremenitve pri času *t*.

Podatki za izračun toplote sončnega sevanja, virov toplote v klimatiziranem prostoru ter pri prezračevanju in infiltracijskem zraku so enaki tistim v [11].

Računalniški program je bil prilagojen za izračun poljubno določenega obdobja v letu z uporabo urnih vremenskih podatkov za vsak vnaprej določen parameter. V programu se metode in enačbe niso spreminjale. To je omogočala podatkovna baza RMY drugega modela, ki je bil urejen in razvit v prejšnji stopnji tega dela. Ta nova razvita verzija programa je bila imenovana CLIMA.

In equation (12), the negative ϕ_t represents heating load and positive ϕ_t represents cooling load at the time *t*.

Information on calculating heat gains from: solar radiation, heat sources within the conditioned space and ventilation and infiltration air are identical to those given in reference [11].

The computer program was re-organized to calculate for an optionally determined period within the year, using the hourly weather data for each of the predetermined physical parameters. Such re-organization was carried out keeping the methodology and equations for hour-by-hour calculations unchanged. It was provided with the RMY Database of the second pattern, which was reorganized and developed in the previous stage of this work. The newly developed version of this program was named CLIMA.

4 UPORABA "SPREMENJENEGA LOS-A0" IN "CLIMA" PROGRAMOV

Spremenjeni računalniški program LOS-A0 in rač.program CLIMA smo uporabili za izračun temperature zraka in toplotnih izgub v poslopjih. Obravnavani prostor je v drugem nadstropju štirinadstropnega poslopja. Prostori nad in pod njim so klimatizirani. Zunanje izmere tega prostora so 3 m × 8,5 m × 8,5 m, površina tal znaša 72,3 m^2. Vsaka zunanja stena ima enojno zastekljeno okno s površino 4,5 m^2.

Z upoštevanjem opisanih navodil za uporabo programa LOS-A0 [12], so bili vneseni podatki zapisani v ločen dokument ″FOR20.DAT″. Ti podatki so:

- značilnosti stavbe,

4 USE OF "THE MODIFIED LOS-A0" AND "CLIMA"COMPUTER PROGRAMS

The modified LOS-A0 and CLIMA computer programs were used to calculate the air temperature and heat loss in an enclosure within a building. The building consists of four floors, the studied enclosure is located on the second floor. The spaces above and under the enclosure are conditioned. The outer dimensions of the enclosure are 3m × 8.5m × 8.5m, with a ground plan area of 72.3m^2. Each outer wall has a single glazed window with an area of 4.5m^2.

Following the described instructions in the LOS-A0 user's guide [12], input data of the enclosure were recorded in the relevant separate file 'FOR20.DAT". The recorded input data are:

- characteristics of the building,

- lokacija, usmerjenost in osenčenost stavbe,
- načrt bivalnih prostorov,
- razsvetljava, število stanovalcev, notranja oprema ter sredstev in procesov, ki prispevajo k notranjim toplotnim virom. Upoštevali smo, da so se stanovalci zadrževali v prostoru od 6:00 do 22:00.

Informacije o metodah vnašanja podatkov dobimo v referenci [12]. Sestava stropa, sten in tal so bili podani glede na sistem plasti od znotraj navzven. Fizikalne lastnosti gradbenih materialov so bile prilagojene območju Damaska ([13] in [14]).

December je bil izbran kot reprezentativni mesec v zimskem obdobju, 21. dan v mesecu pa kot reprezentativen dan. Temperaturna porazdelitev v mesecu decembru je ekstremno nizka glede na temperaturno porazdelitev v novembru, januarju in februarju.

Rezultati izračunov so zapisani v dokumentu FOR21. DAT in nekateri glavni podatki so grafično prikazani na slikah 1 in 2. Tam vidimo temperaturo zraka in obnašanje toplotnega toka v prostoru za 21. december.

- building location, orientation and external shading,
- indoor design conditions,
- proposed schedule of lighting, occupants, internal equipment, appliances and processes that would contribute to the internal thermal load. Occupation of the enclosure from 6:00 through to 22:00 hours was considered.

Information on the methodology for recording them is available in reference [12]. Compositions of the ceiling, walls and floor were described, taking into account that the systematization of layers starting from the inside towards the outside. The physical properties of building materials used in the Damascus zone were adopted ([13] in [14]).

December is adopted in the analysis as a representative month for the winter season and the 21st as its representative day. The temperature distribution in December is characteristic of an extremely cold month compared with the temperature distribution in November, January and February. Furthermore, the 21st of each month is representative of the conditions on average cloudless days.

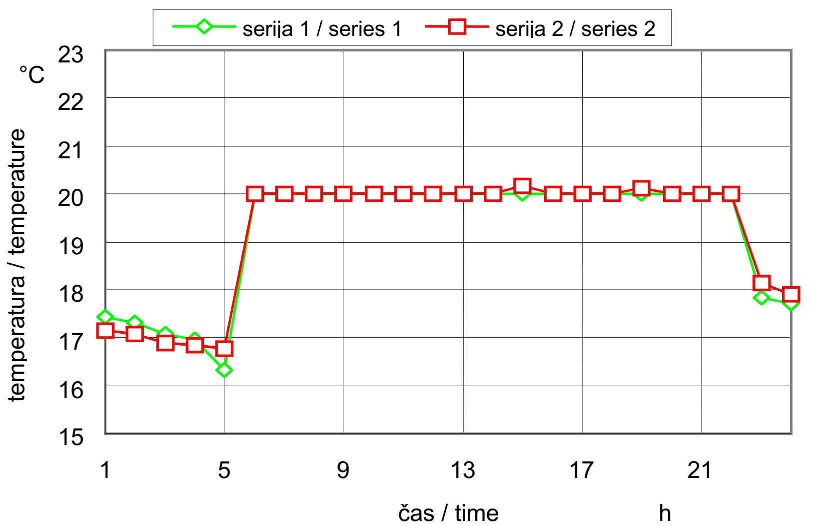
The results of calculations were recorded in a separate file FOR21.DAT and some of the main output data are graphically presented in figures 1 and 2. These figures show the enclosure air temperature and heat flow behavior, respectively, for the 21st day of December.

5 UGOTOVITVE IN SKLEP

Vremenski podatki za območje Damaska od leta 1970 do 1993, ki jih zahteva program LOS-A0, so bili natančno pregledani in obdelani. S temi merjenimi podatki je bila podatkovna baza RMY urejena in

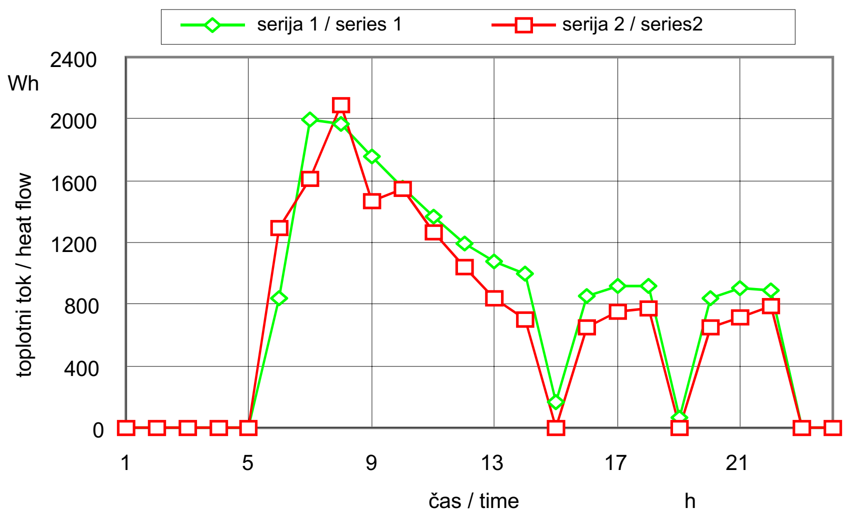
5 DISCUSSION AND CONCLUSION

The weather data for the Damascus zone measured for the years 1970 through 1993, which are required in the existing computer programs LOS-A0, were scrutinized and reconditioned. Using these



Sl. 1. *Obnašanje temperature zraka za 21. december (1 - z uporabo spremenjnenega računalniškega programa LOS-A0 - podatkovna baza RMY za mesečno povprečje urnih vremenskih podatkov, 2 - z uporabo računalniškega programa CLIMA - podatkovna baza RMY za urne vremenske podatke)*

Fig. 1. *Enclosure air temperature behavior for the 21st of December (1- using modified LOS-A0 computer program -RMY Database for monthly average of hourly weather data, 2- using CLIMA computer program - RMY Database for hourly weather data)*



Sl. 2. *Obnašanje toplotnega toka za 21. december (1 - z uporabo spremenjenega računalniškega programa LOS-A0 - podatkovna baza RMY za mesečno povprečje urnih vremenskih podatkov, 2 - z uporabo računalniškega programa CLIMA - podatkovna baza RMY za urne vremenske podatke)*

Fig. 2. *Enclosure heat flow behavior for the 21st of December (1- Using the modified LOS-A0 computer program -RMY Database for monthly average of hourly weather data, 2- Using CLIMA computer program -RMY Database for hourly weather data)*

razvita glede na naslednje vzorce:
- urno mesečno povprečje,
- urno povprečje,
- dnevna količina sonca, merjena v urah.

Računalniški program LOS-A0 je bil pripravljen skupaj s podatkovno bazo prvega modela. Prilagojen je bil glede na delovne razmere in letne čase v Siriji.

Omenjeni program je bil dopolnjen za izračun poljubnega obdobja v letu in ta različica se imenuje CLIMA. Ta pa je bil pripravljen skupaj s podatkovno bazo drugega modela.

Spremenjena programa LOS-A0 in CLIMA sta bila uporabljena za energijske analize prostora. Natančne analize rezultatov, dobljenih z uporabo obeh programov, so pokazale, da so vrednosti za temperaturo zraka skladne (sl. 1). Vrednosti za toplotne izgube so se razlikovale (sl. 2). Največjo vrednost toplotnih izgub dobimo z uporabo povprečnih urnih podatkov o vremenu, najnižjo vrednost pa z izračunom urnih vremenskih podatkov. Ti odmiki se pojavljajo zaradi povprečnih urnih vremenskih podatkov za mesec december in tipičnih urnih vremenskih podatkov za 21. december. Dobljeni mesečni toplotni dobitki z uporabo spremenjenega LOS-A0 in CLIMA so 567,2 kWh in 279,2 kWh. Kakorkoli že, čas računanja z uporabo osebnega računalnika s procesorjem PENTIUM 166 sta bila 0,66 s in 3,35 s. Iz teh števil je razvidno, da je vrednost toplotnih obremenitev, izračunana po spremenjenem LOS-A0, precenjena. Ta precenjenost je posledica kumulativnih dnevnih razlik v izračunu toplotnih obremenitev skozi ves december. Bolj natančne rezultate dobimo z

measured data, an RMY Database was organized and developed according to the following patterns:
- monthly average of the hourly weather data,
- hourly weather data,
- daily sunshine hours.

The LOS-A0 computer program was provided with an RMY Database of the first pattern. It was also modified to be adapted for utilization according to working conditions and weather seasons in Syria.

The last mentioned program was re-organized, to be used in the calculation for an optionally determined period within the year, and a new version, CLIMA, was obtained. The CLIMA computer program was provided with an RMY Database of the second pattern.

Modified LOS-A0 and CLIMA computer programs were utilized in the energy analysis of an enclosure. Detailed analysis of the results calculated by the two programs revealed that the values obtained for air temperature behavior were in good agreement (Fig. 1). The values for heat loss behavior were, however, different (Fig. 2). The highest values of heat loss are obtained by using the monthly average of hourly weather data, and the lowest values are obtained by using the hourly weather data. Such deviations are due to the discrepancies between the monthly average of hourly weather data for the month of December and the typical hourly weather data for the 21st of December. Moreover, the obtained monthly heat load by using the modified LOS-A0 and CLIMA were 567.2 kWh and 279.2 kWh respectively. However, the computing times using a PC with a PENTIUM 166 processor were 0.66 seconds and 3.35 seconds respectively. From these figures it can be seen that the value of heat load calculated by the modified LOS-A0 is an overestimation. Such an overestimation is due to the uporabo urnih vremenskih podatkov namesto uporabe mesečnega povprečja urnih vremenskih podatkov.

Toplotna zmožnost ter stroški ogrevanja in klimatizacije so sorazmerni s toplotnimi obremenitvami in zato je pomembno, da je podatkovna baza dostopna, saj omogoča natančen izračun, katerega posledica je zmanjšanje porabe energije. Računalniški program CLIMA priporočamo za dinamične analize prenosa toplote v stavbah, skupaj s podatkovno bazo RMY, v kateri so predstavljeni urni vremenski podatki določenega fizikalnega parametra.

cumulative daily discrepancies in the calculated heat load over all the days of December. More accurate results are obtained by the use of hourly weather data instead of using the monthly average of hourly weather data.

Since the thermal capacity and cost of heating and air-conditioning systems are proportional to the heat load and since an RMY Database is available it is important that accurate results are achieved to reduce energy consumption. Therefore, the use of the CLIMA computer program for the dynamic analysis of heat transfer in buildings, provided with an RMY Database in which the hourly weather data of predetermined physical parameters are represented, is suggested.

ZAHVALA

Avtor se zahvaljuje prof.dr. Ibrahim-u Othman-u, generalnemu direktorju, za izraženo zanimanje in vzpodbude ter prof.dr. Tawfik-u Kassam-u in dr. Mohamed-u Tlass-u za razprave in nasvete. Končno gre zahvala tudi Oddelku za meteorologijo za pridobitev uporabljenih urnih vremenskih podatkov za Damask.

ACKNOWLEDGMENT

The author would like to express his gratitude to Prof. Dr. Ibrahim Othman, the Director General, for his continued interest and encouragement and to Prof. Dr. Tawfik Kassam and Dr. Mohamed Tlass, for valuable discussions and suggestions. Finally, thanks are due to the Department of Meteorology, for providing the determined hourly weather data for the Damascus zone.

6 OZNAČBE
6 NOMENCLATURE

površina A	A	surface A
spremenljivka a; element matrike [a]	a	variable a; elements of matrix [a]
spremenljivka b; element matrike [b]	b	variable b; elements of matrix [b]
specifična toplota zraka	c_p	air specific heat
razlika	D	difference
kritična vrednost Kolmogorovovega testa	$D_n^{(\gamma)}$	critical values of the Kolmogrov goodness-of-fit test
funkcija standardne normalne kumulativne porazdelitve	$F(z)$	standard normal cumulative distribution function
funkcija normalne gostote verjetnosti	$f(x)$	normal probability density function
koeficient sevalnega prenosa toplote	g	radiation heat transfer coefficient
spremenljivka x ima kumulativno krivuljo frekvence F(z)	H_0	the variable x has cumulative frequency curve F(z)
spremenljivka x nima kumulativne krivulje frekvence F(z)	H_1	the variable x does not have cumulative frequency curve F(z)
j-ti element	J	j-th element
število površin prostora	m	number of surfaces in the enclosure
število TRF; število točk	n	number of TRF; number of points
verjetnost	P	probability
odklonilno področje; stopnja energije, ki jo sevajo notranji viri toplote (sončna energija, ki prihaja skozi okna, razsvetljava, oprema in ljudje v prostoru) in ki jo absorbira površina i v času t; stopnja energije, ki se prenese na okoliški zrak s prestopom z notranjih virov toplote (sončna energija, ki prihaja skozi okna, razsvetljava, oprema in ljudje v prostoru) v času t	R	rejection region; rate of heat radiated from the internal heat sources (solar energy coming through the windows, lights, equipment and occupants) and absorbed by surface i at time t; rate of heat convected into the enclosure air from the internal heat sources (solar energy coming through the windows, lights, equipment and occupants) at time t
specifični toplotni/masni tok	q	specific heat/mass flow
funkcija kumulativne porazdelitve frekvence	S	sample cumulative frequency distribution function

spremenjeni TRFs	X	modified TRFs
spremenljivka x	x	variable x
aritmetično povprečje vzorca	$\overline{x}$	arithmetic mean of the sample
spremenjeni TRFs	Y	modified TRFs
standardna normalna spremenljivka	z	standard normal variable
koeficient prestopa toplote	α	convection heat transfer coefficient
stopnja pomembnosti preskusa	γ	level of significance of the test
aritmetično povprečje/pričakovano povprečje	μ	arithmetic mean/expected mean
standardno odstopanje	σ	standard deviation
temperatura	ϑ	temperature
toplotna obremenitev	ϕ	thermal load
tip oblačnosti	CTYP	type of cloud
temperatura suhega termometra	DBT	air dry-bulb temperature
temperatura rosišča	DPT	air dew-point temperature
eksponent	exp	exponent
največja vrednost	max	maximum
mesec	MON	month
celotno sončno sevanje	MGO	global solar radiation
model normalne porazdelitve	NDM	normal distribution model
relativna vlažnost	RH	relative humidity
referenčno meteorološko leto	RMY	reference meteorological year
atmosferski tlak	SP	atmospheric pressure
splošni delež	SR	common relation
stopnja celotne oblačnosti	TC	degree of global cloudless
toplotni odzivni faktorji	TRFs	thermal response factors
temperatura vlažnega termometra	WBT	air wet-bulb temperature
smer vetra	WD	wind direction
hitrost vetra	WS	wind velocity

Indeksi:	**Subscripts:**	
prenešena toplota v okoliški zrak iz notranjih virov toplote v času t	ci,t	convected into the enclosure air from the internal heat sources at time t
i-ta površina	i	i-th surface
notranja površina i	ii	interior surface i
notranja površina i v času t	ii,t	interior surface i at time t
notranja površina i v času t-j	ii,t-j	interior surface i at time t-j
i-ta površina v času t	i,t	i-th surface at time t
i-ta površina v času t-1	i,t-1	i-th surface at time t-1
notranji zrak v času t	ia,t	inside air at time t
notranja površina k v času t	ik,t	interior surface k at time t
površina i glede na površino k	i,k	surface i in respect to surface k
spremenjen TRF j za površino i, elementi i=1,2……m+1 in j=1,2…….m+1	i,j	modified TRF j for the surface i, elements i=1,2……m+1 and j=1,2…….m+1
j-ti element	j	j-th
zunanja temperatura površine i v času t-j	oi,t-j	outside temperature of surface i at time t-j
zunanji zrak v času t	oa,t	outdoor air at time t
masni pretok zunanjega zraka, ki prehaja v okolico v času t	mf,t	mass flow of outdoor air infiltrating into the enclosure at time t
masni pretok ventilacijskega zraka v času t	mv,t	mass flow of ventilation air at time t
največja vrednost	max	maximum
n-ti element	n	n-th
ventilacijski zrak v času t	v,t	ventilation air at time t
toplota,ki jo sevajo notranji viri toplote in jo absorbira površina i v času t	si,t	radiated from the internal heat sources and absorbed by surface i at time t
čas	t	time

7 LITERATURA
7 REFERENCES

[1] Saman, H. (1995) Energy balance in the Syria Arab Republic. *Internal statistical report, Ministry of petroleum*, Syria.
[2] Skeiker, K. (1990) LOS-A0, The computer program for dynamic analysis of heat transfer in building, Faculty of mechanical engineering in Ljubljana, Slovenia.
[3] Martz, H.V. (1991) Bayesian reliability analysis. *Krieger publishing company, Malabar*, Florida.
[4] Preston, D.V. (1991) The art of experimental physics. *John Wiley and Sons,* New York.
[5] Green, J.R. (1979) Statistical treatment of experimental data, *Elsevier Scientific Publishing Company,* New York.
[6] Goon, A.M. (1981) Basic statistics. *The world press private limited*, Calcutta.
[7] Brookes, B.C. (1967) Introduction to statistical method, *Heinemann,* London.
[8] Miller, J.C. (1993) Statistics for analytical chemistry, 3rd edition, *Ellis Horwood limited*, New York.
[9] Kusuda,T. (1969) Thermal response factors for multi-layer structure of various heat conduction systems. *ASHRAE Transactions*, Vol. 75, Part I.
[10] Stephenson, D.G. and G.P. Mitalas (1971) Calculation of heat conduction transfer functions for multi-layer slabs. *ASHRAE Transaction*, Vol. 77, Part II.
[11] ASHRAE (1995) ASHRAE handbook- Fundamentals, SI Edition, *American society of heating refrigerating and air-conditioning engineers inc.,* Atlanta.
[12] Zupančič, J. (1985) LOS-A0 Computer program for the building heating and cooling load calculation (Adopted NBSLD Program). *Faculty of mechanical engineering*, Ljubljana.
[13] Eldridge, H.J. (1974) Properties of building materials. *MTP company limited*, Great Britain.
[14] Rateb, S. (1998) Properties of building materials. *Faculty of civil engineering,* Damascus, Syria.

Naslov avtorjev: Kamal Skeiker
Komisija za jedrsko energijo
Oddelek za znanstvene storitve
p.p. 6091
Damask, Sirija

Authors' Address: Kamal Skeiker
Atomic Energy Comission
Department of Scientific Services
P.O. Box 6091
Damascus, Syria

Prejeto:
Received: 29.9.1999

Sprejeto:
Accepted: 2.6.2000